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Behavior-Based Freight Modeling at Metro

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Metro

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PSU Transportation Seminar:
Metro Freight Model

May 5th, 2017

Agenda

Project Background

Model Framework

1) Firm Synthesis
2) Supply Chain
3) Freight Truck Tours
4) Commercial Vehicle Tours

Dashboard (time permitting)

Keywords: disaggregate, behavior, tour

Project Background

Acknowledgements

- Metro: Bud Reiff, Dick Walker
- RSG: Colin Smith, John Gleibe, Maren Outwater
- DKS: Bob Schulte

Questions Facing the Region (1)

Regional economy

- Economic impacts of freight system level of service, e.g. on export industries
- Port competitiveness in global freight movements

Network congestion

- Traffic congestion on the interstates and near industrial areas
- Critical bottlenecks in Portland region's rail infrastructure
- Weight and clearance restrictions on bridges
- Corridor capacity constraints and travel time reliability

Questions Facing the Region (2)

Land use impacts

- Expansion of current industrial and warehousing areas. Planning and design of future areas.
- Impacts from freight operations on residential neighborhoods

Policy analysis

- Ability to quantify the effects of freight policy choices on specific commodities and types of businesses
- Explore feasibility of electric vehicles for typical truck itineraries

Project Goals

1. Evaluate regional economic policies
2. Broad range of responses to network conditions and costs
3. Depict both truck volumes by vehicle type and flow of goods by commodity type on the network
4. Include freight trucks AND service and parcel trucks

Benefits to the Region

Improved ability to evaluate cost of congestion and benefits of freight improvements

Improved understanding of land use policies, e.g., role of warehousing and distribution

Improved understanding of truck –related environmental impacts, potential for electric freight vehicles, effects of route restrictions, etc.

Scope of Work / Deliverables

1. Implementation Plan
2. Data Plan
3. Implement FHWA Demonstration freight model

SHRP2

4. Freight Data
   - Behavioral data (surveys, truck trip records, etc)
   - Observed data (truck counts, etc)
   - Model input data.

STP + LM

5. Survey Findings, Data Summary, Model Update Plan
6. Develop Working Model Reflecting Local Freight Behavior.
7. Calibrate / Validate Final Model
8. Final report

SHRP2

Project Budget/Schedule

Awarded $350,000 SHRP2 C20 Implementation Assistance Grant April 2014

Metro approved additional $350,000 STP Funds for freight data

Metro also provided $41,000 in-kind local match for data development

Contractor DKS / RSG / Synergy began work March 2015

Contract ended May 1, 2017

New “Hybrid” Freight Model

New generation of “hybrid” model that micro-simulates both commodity supply chains and local truck tours

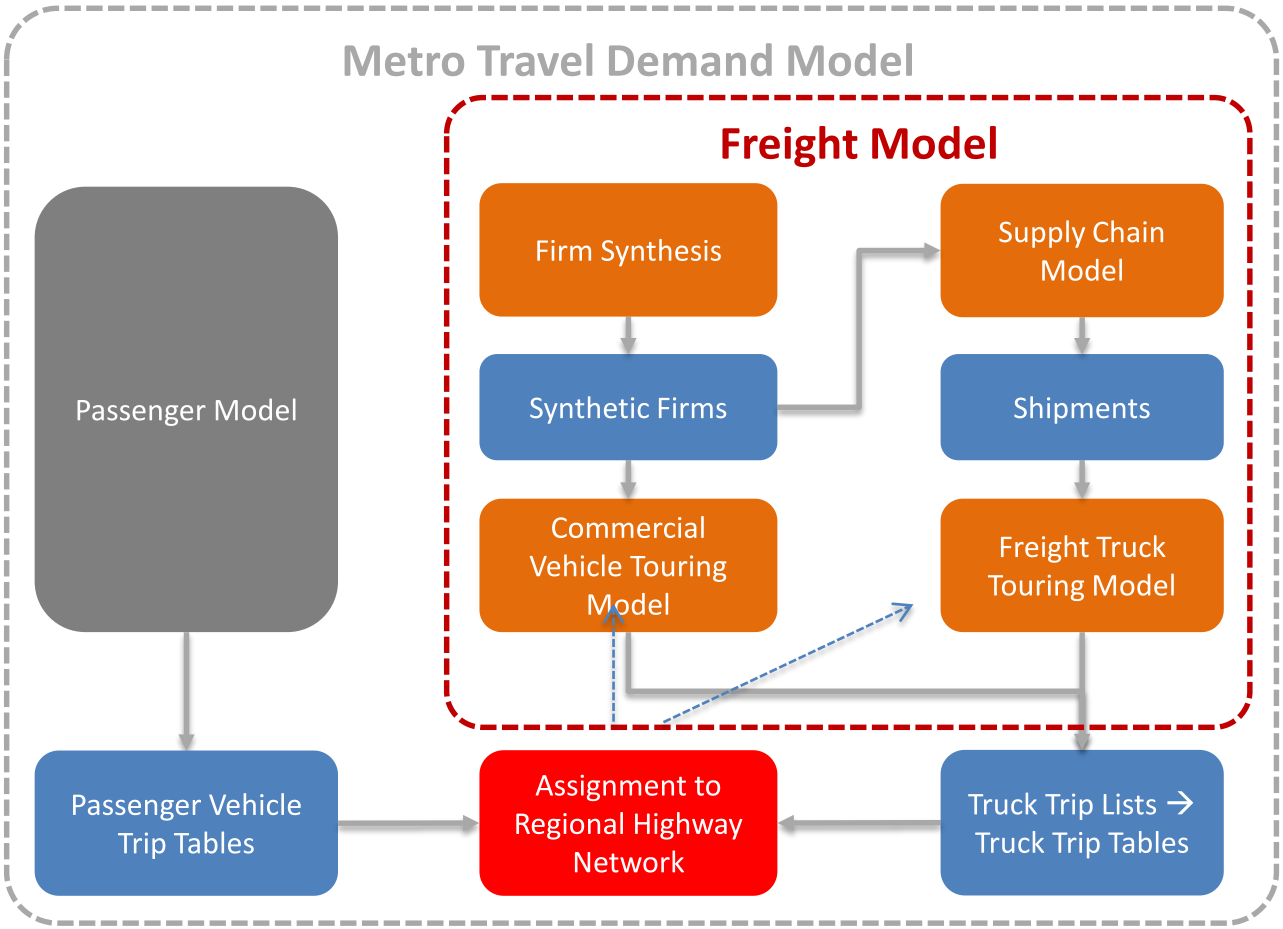
- Similar applications in Chicago, Baltimore, Phoenix, Florida

Enabled by new data sources and methods:

- Improved techniques for mining Commodity Flow Survey (CFS) and FAF data to enable simulation of firms and shipments
- New truck behavior data to enable simulation of truck movements
  - Detailed business establishment surveys (e.g., Ohio, Texas, Portland) with truck itineraries. Including both freight and service industries.
  - GPS traces of truck movements by vehicle class (e.g., INRIX, EROAD, ATRI)
  - Dispatch data maintained by businesses (and donated for model development)

Overall Model Framework

Freight Model Design



Design Overview

Overall Model Structure

- Integrates data from multiple spatial / geographic levels
- Designed for integration within the Metro Travel Demand Model

Firm Synthesis Model

- Synthesizes a set of business establishments that ship and receive freight and (in the region) provide services

Supply Chain Model

- Model annual commodity movements and shipment flows by mode

Freight Truck Touring Model

- Models pick up and delivery of freight shipments within the region

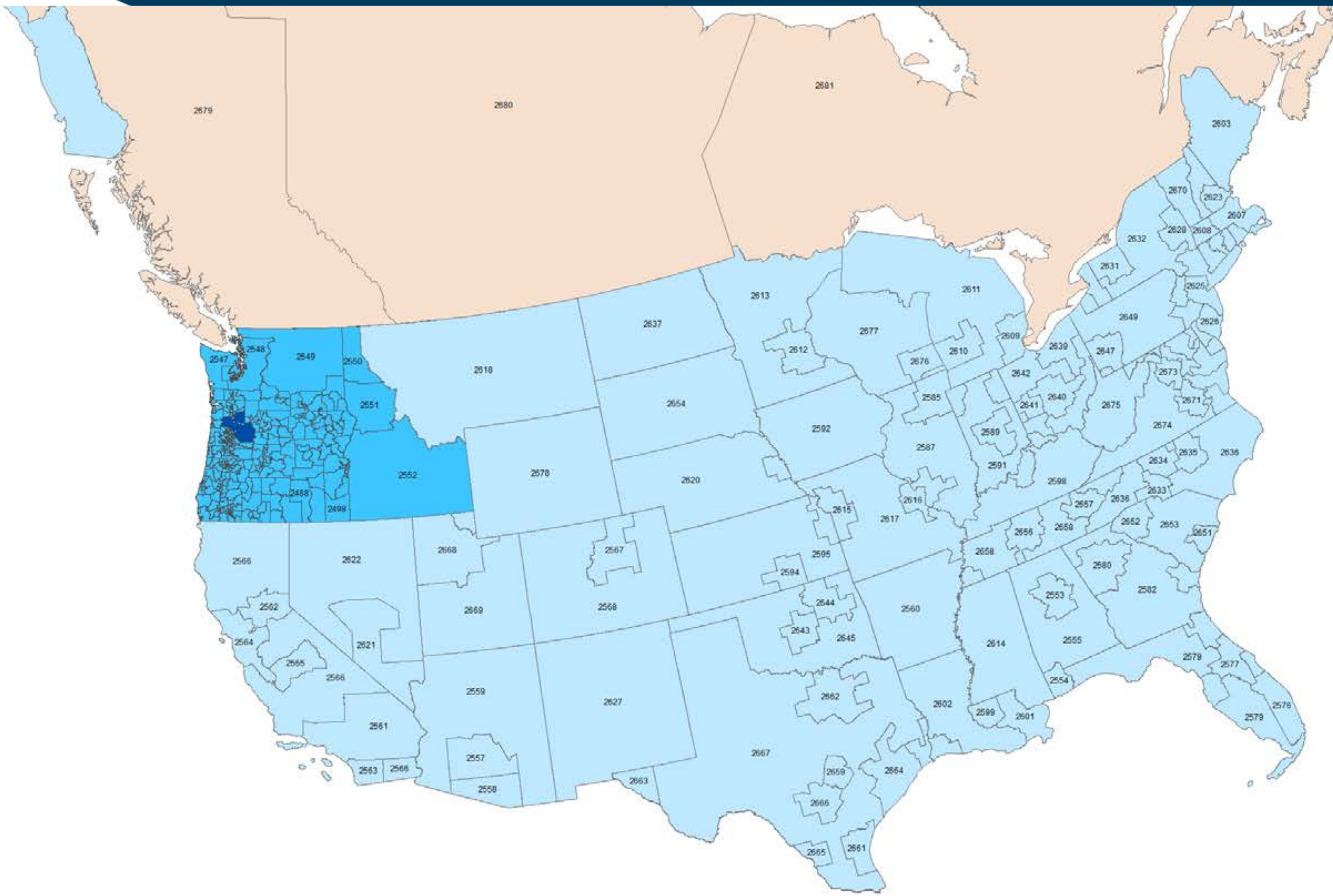
Commercial Vehicle Model

- Models commercial vehicle movements in the region, all purposes other than freight shipment delivery to businesses

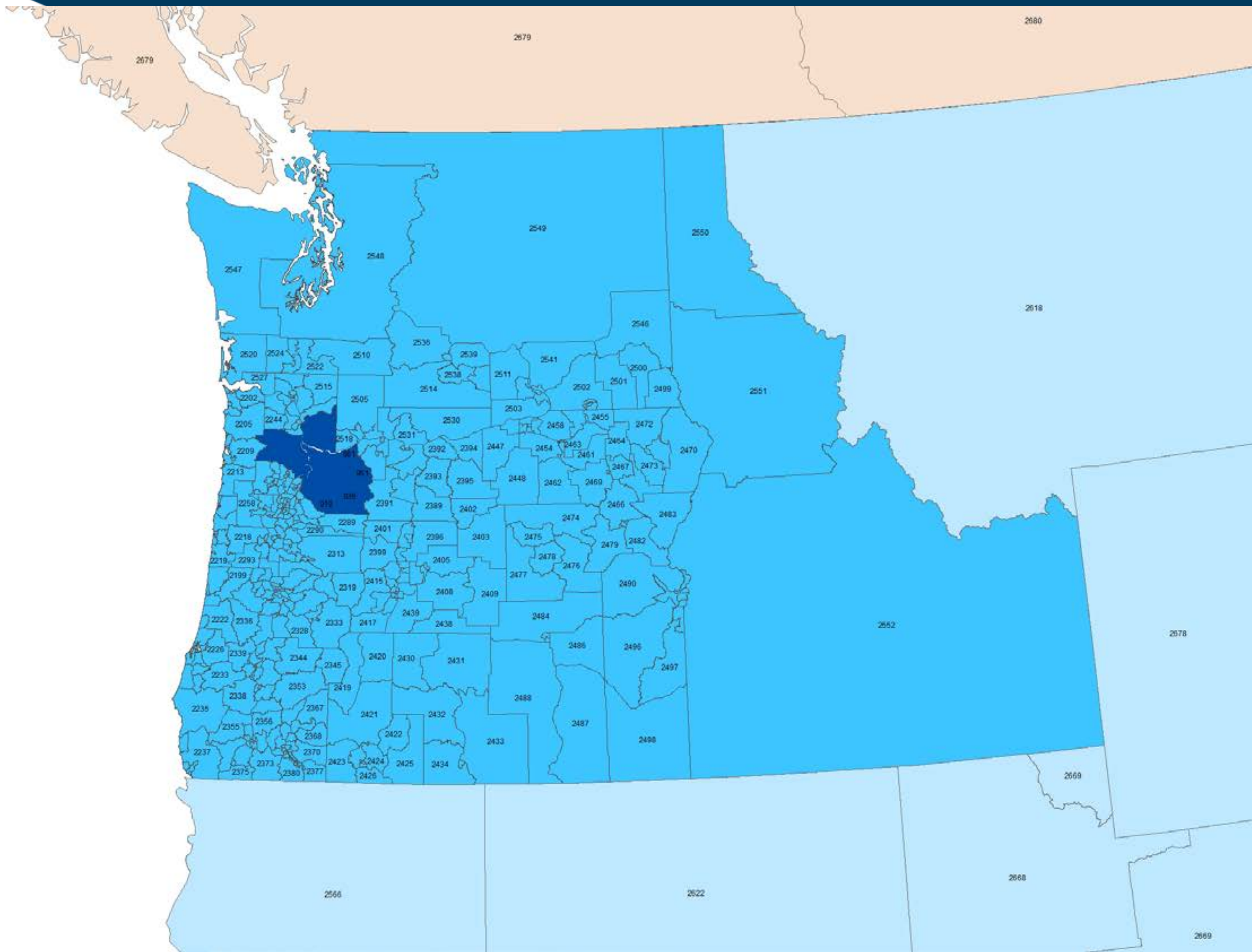
Multiple Spatial Levels

- National Supply Chain Model
  - Includes all of U.S, Canada, and external foreign zones
  - Uses FAF4 regions
  - National highway, rail, air, and water networks
- Oregon and portions of Washington and Idaho
  - Uses Oregon Statewide Integrated Model (SWIM) “Beta Zones”
  - Includes Interstate, State, and County highways, short line railroads, Columbia/Snake and Willamette waterways
- Portland Metro Area
  - Uses Metro model network and zones
  - Accounts for rail yard, airport, and port access
  - *Local rail spur and private dock access not currently accounted for*

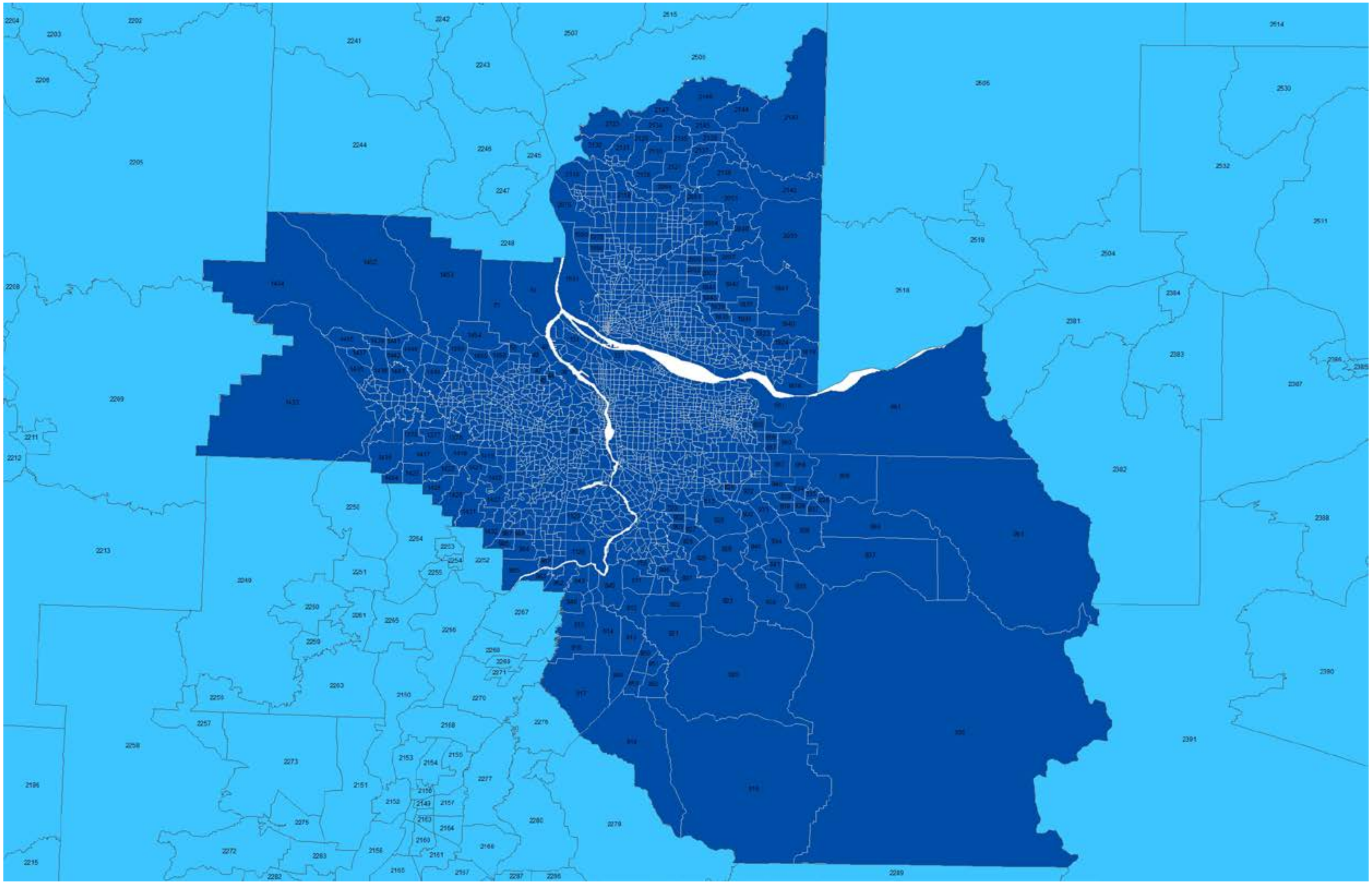
Multiple Spatial Levels - National



Multiple Spatial Levels - Regional

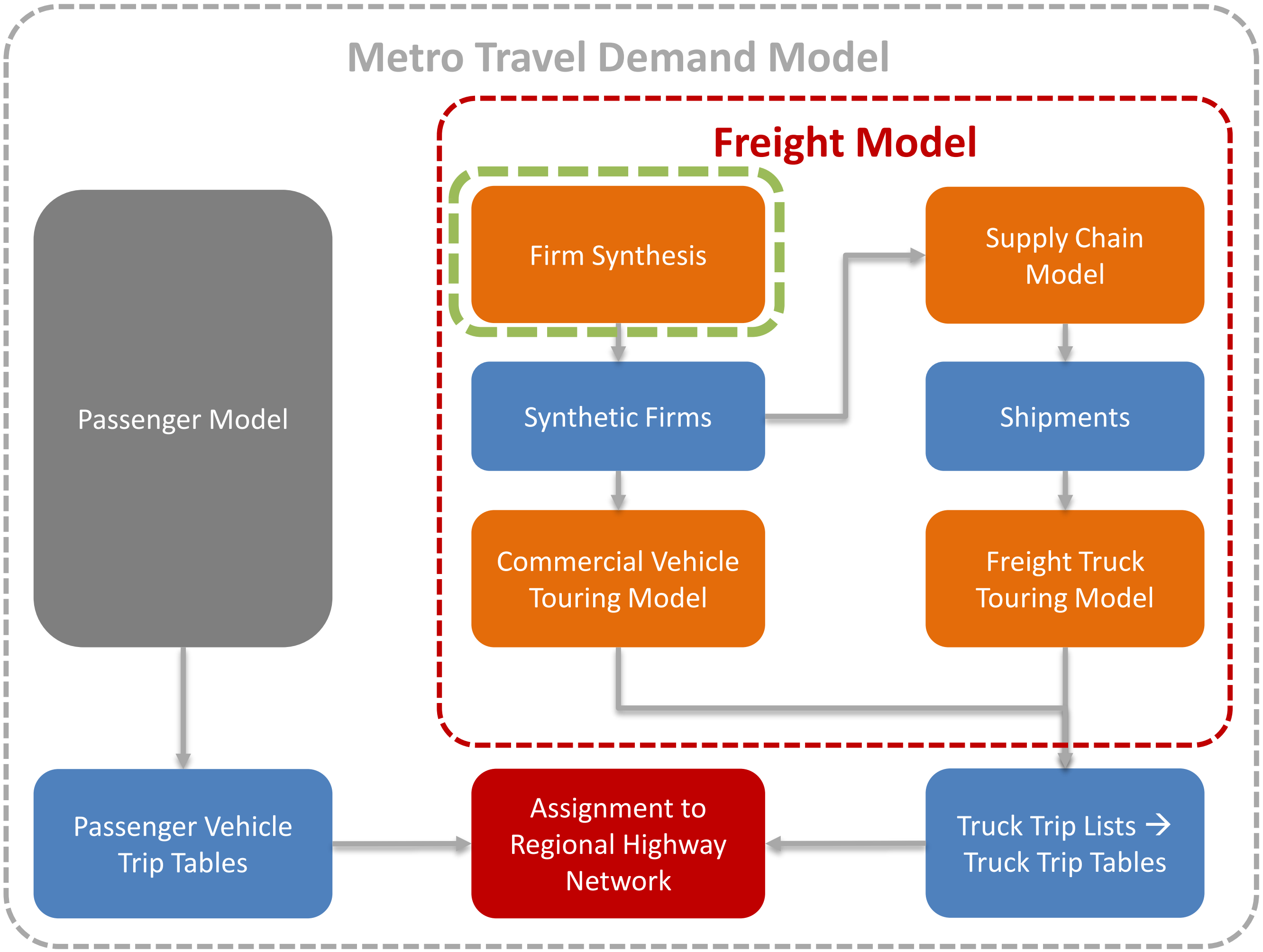


Multiple Spatial Levels - Local

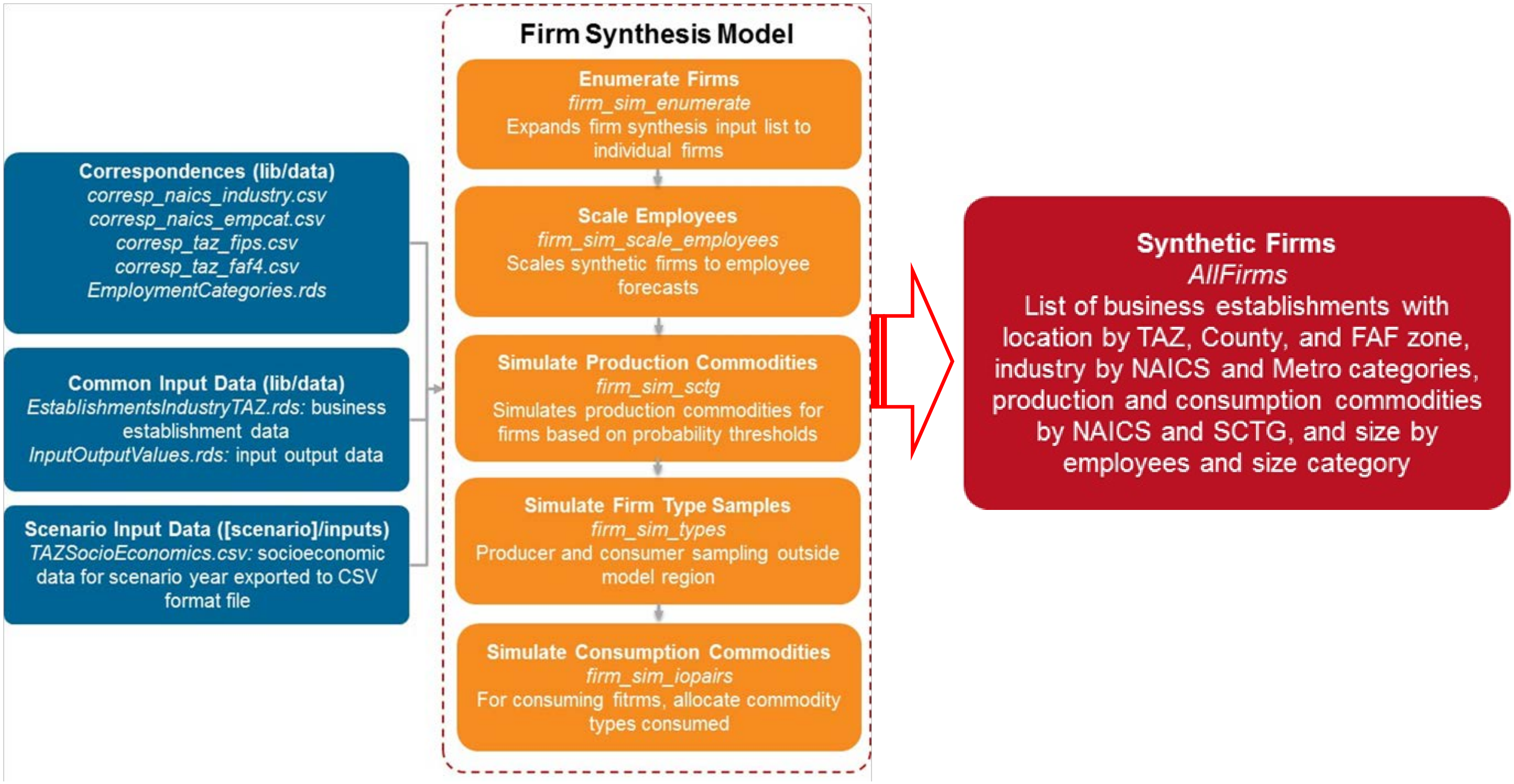


Firm Synthesis Model

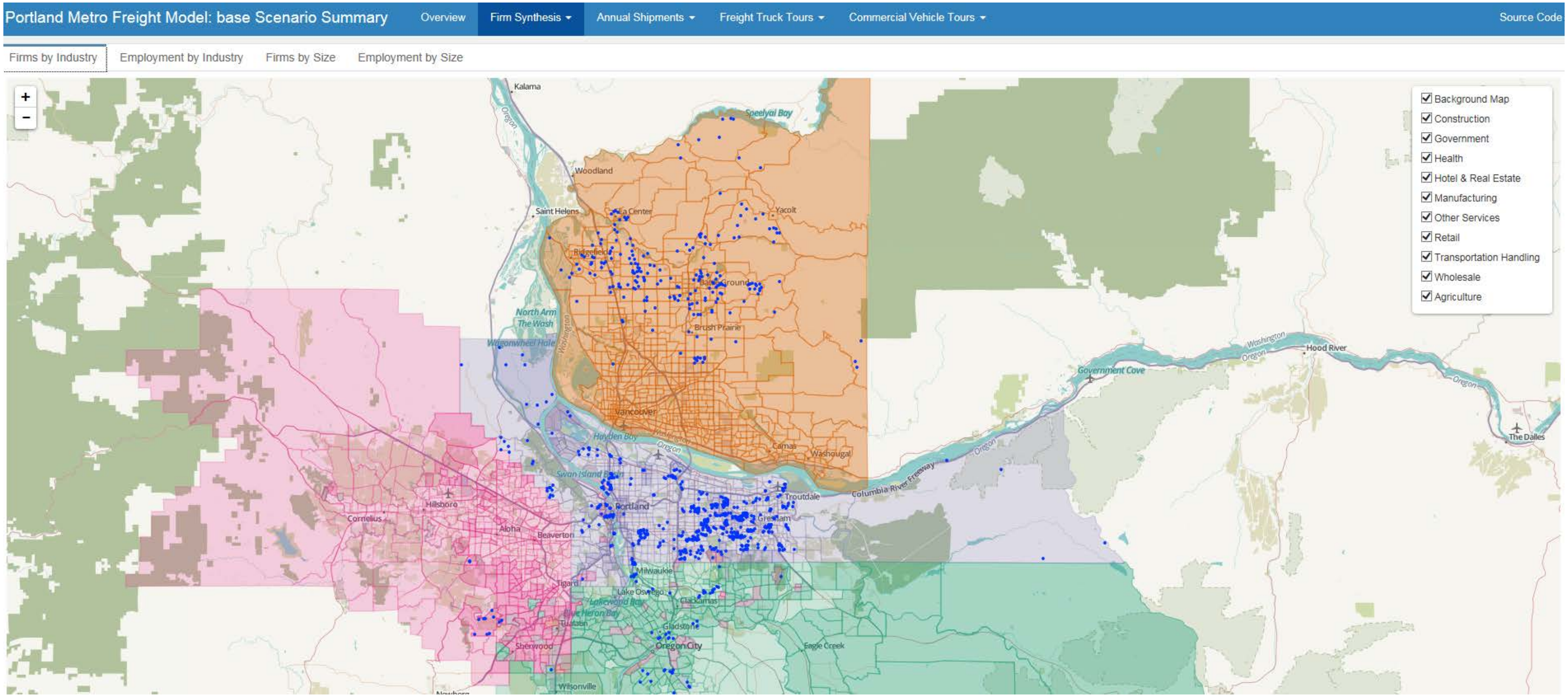
Firm Synthesis



Firm Synthesis Model Structure



Synthesized Firms



Supply Chain Model

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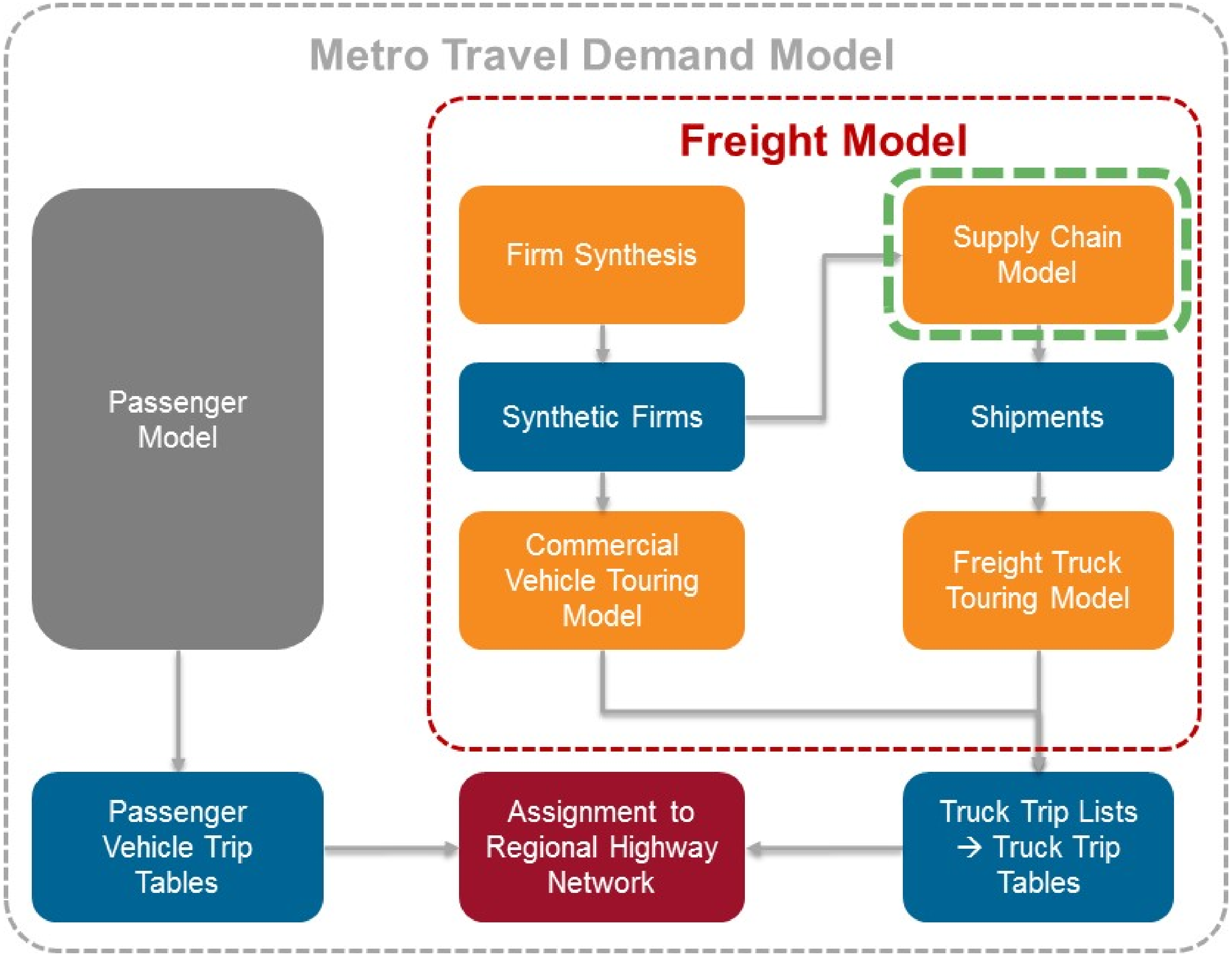


National Supply Chain Framework

Firm Synthesis
Synthesizes a list of businesses in the model region, the rest of the US, and an international sample

Supplier Selection
Connects suppliers to buyers based on the commodities produced by the supplier and consumed by the buyer

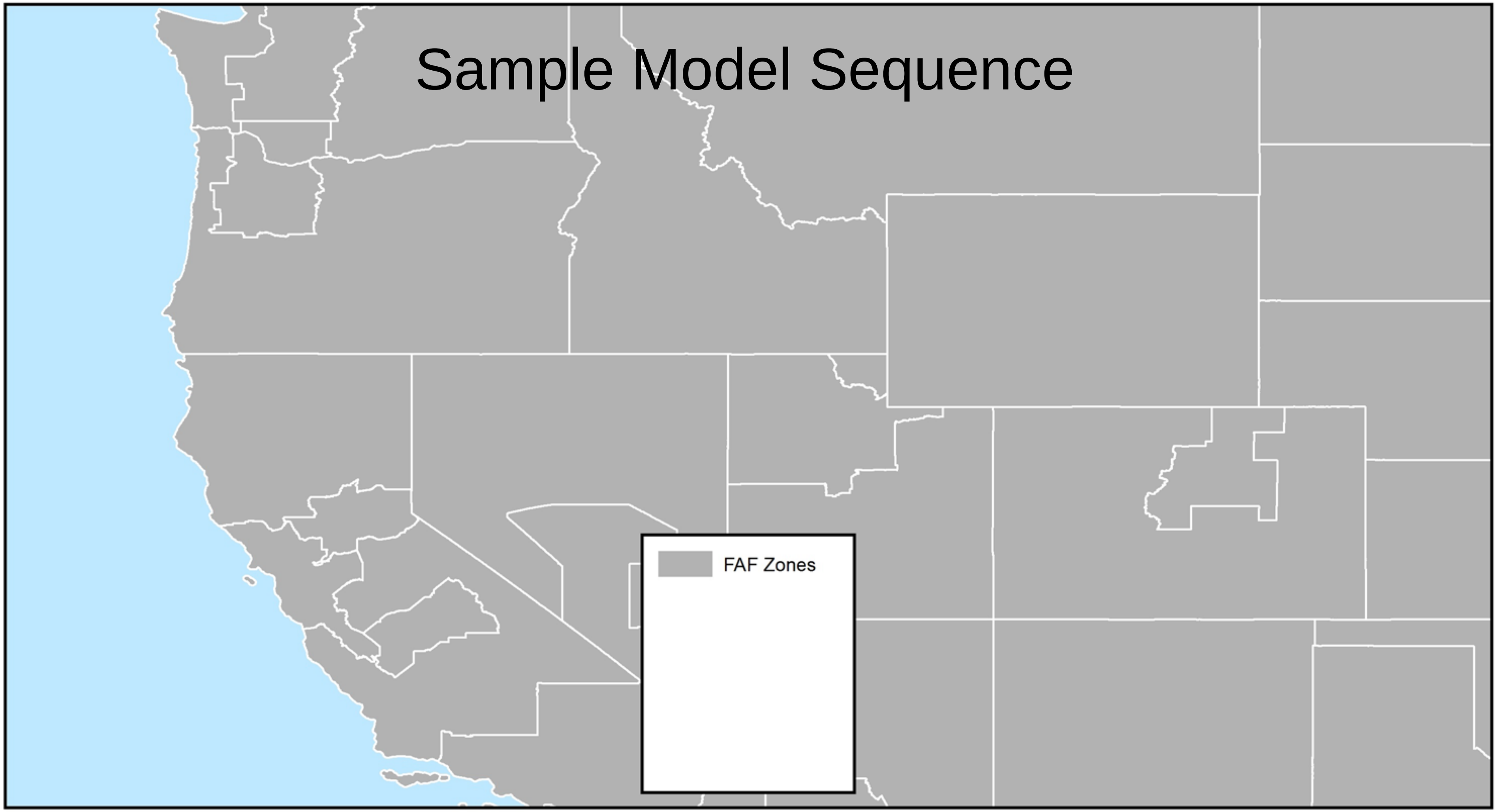
Goods Demand
Distributes commodity flows amongst the paired suppliers and buyers

Distribution Channel
For each buyer/supplier pair, selects whether shipments are direct or involve intermediate handling (intermodal, distribution center)

Shipment Size
For each buyer/supplier pair, converts an annual commodity flow to shipments by size and frequency

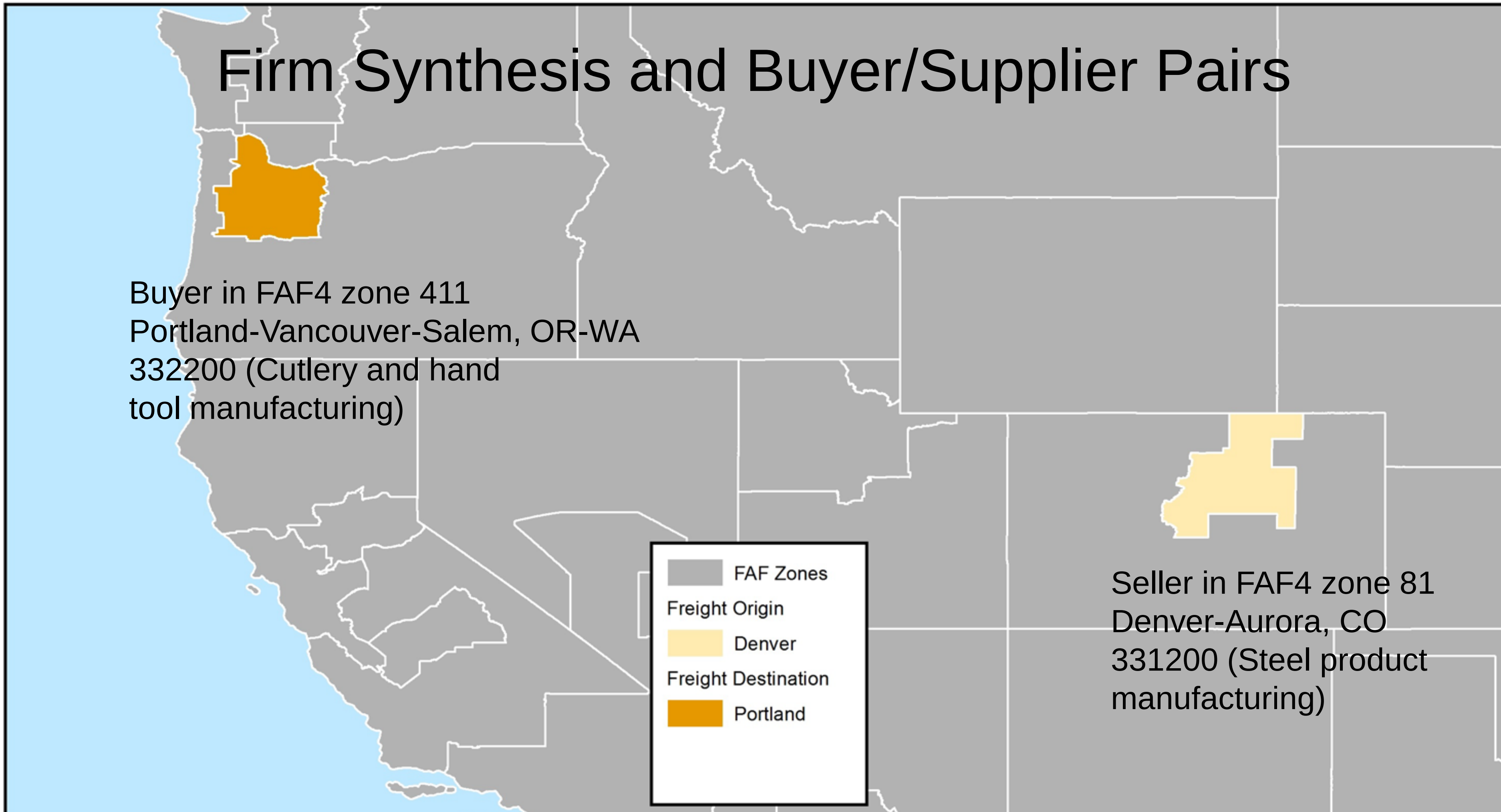
Mode and Transfers
Identifies the mode for each leg of the trip from supplier to buyer and the transfer locations

Sample Model Sequence: Supply Chains



Sample Model Sequence: Supply Chains

Firm Synthesis and Buyer/Supplier Pairs



Buyer in FAF4 zone 411
Portland-Vancouver-Salem, OR-WA
332200 (Cutlery and hand
tool manufacturing)

Seller in FAF4 zone 81
Denver-Aurora, CO
331200 (Steel product
manufacturing)

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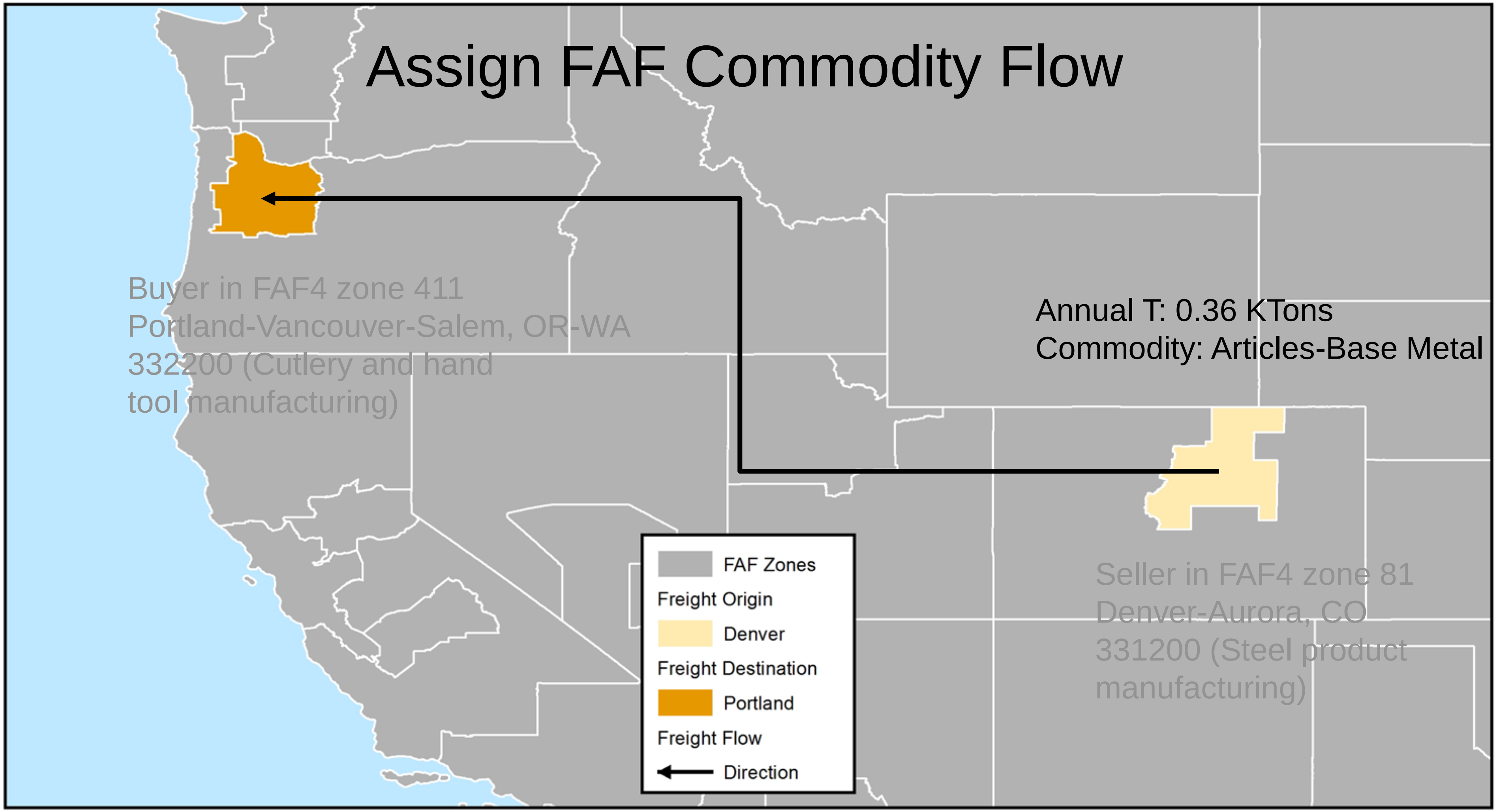

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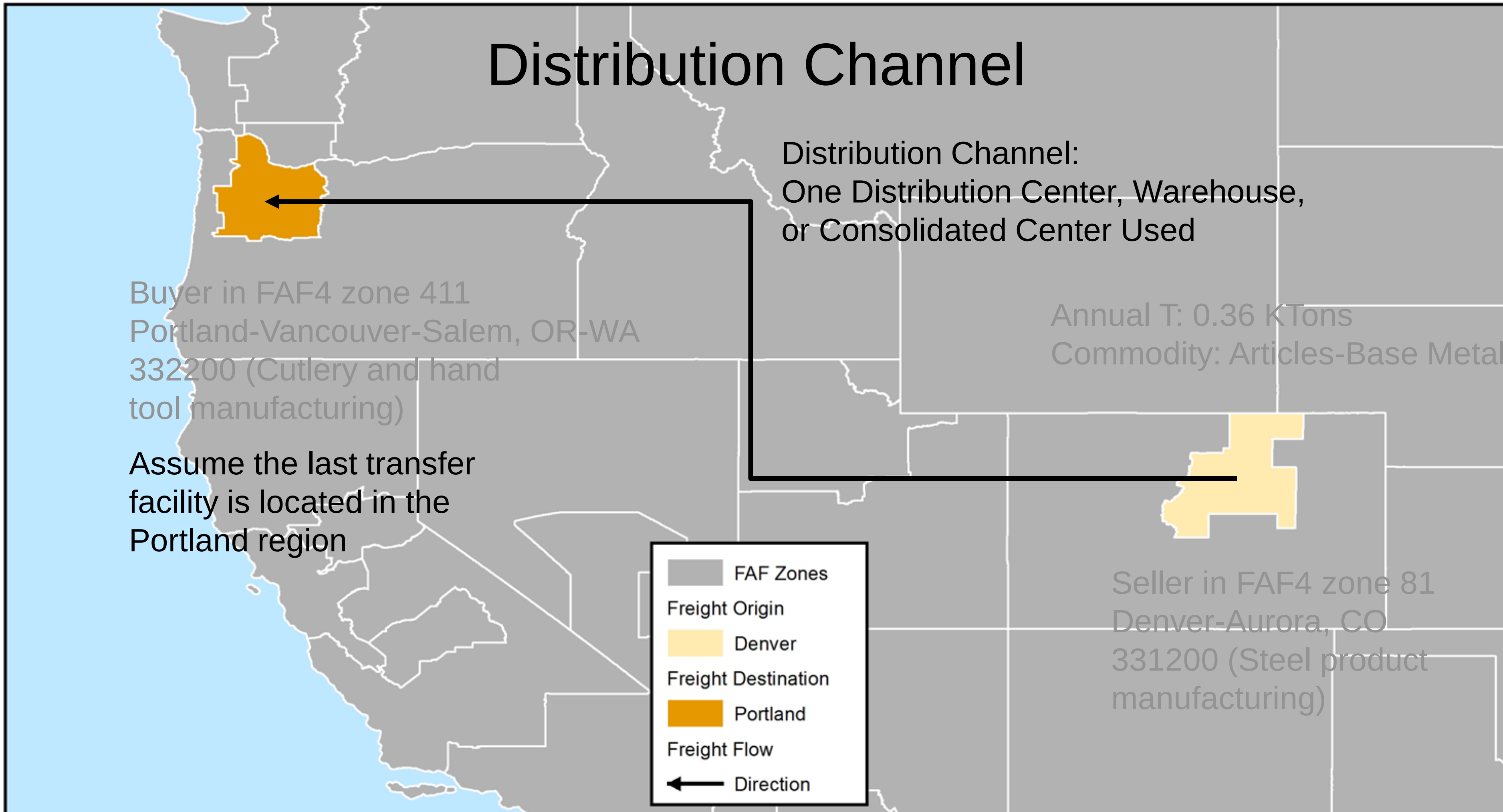

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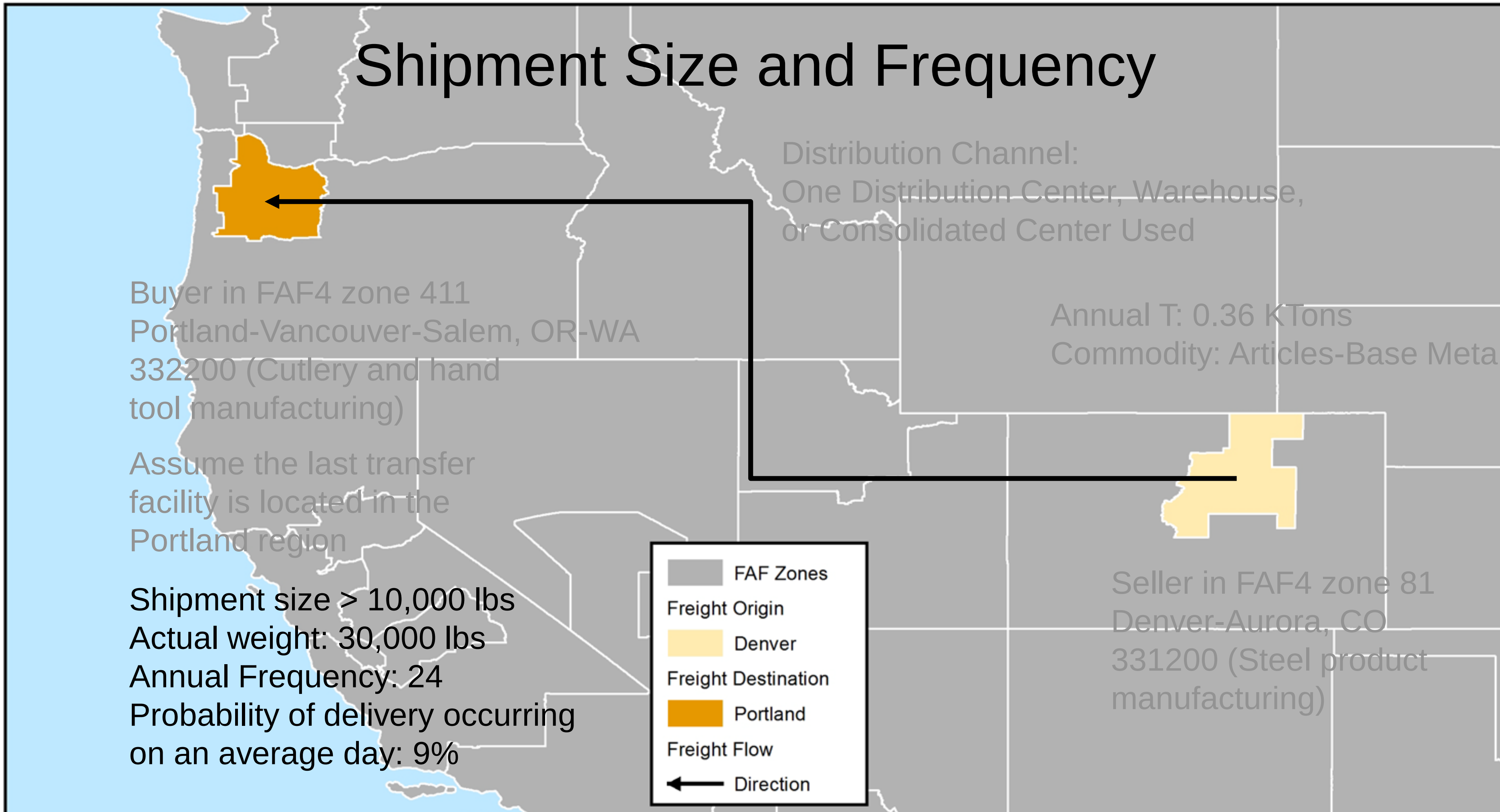


Shipment Size and Frequency

Distribution Channel:
One Distribution Center, Warehouse, or Consolidated Center Used

Buyer in FAF4 zone 411
Portland-Vancouver-Salem, OR-WA
332200 (Cutlery and hand tool manufacturing)

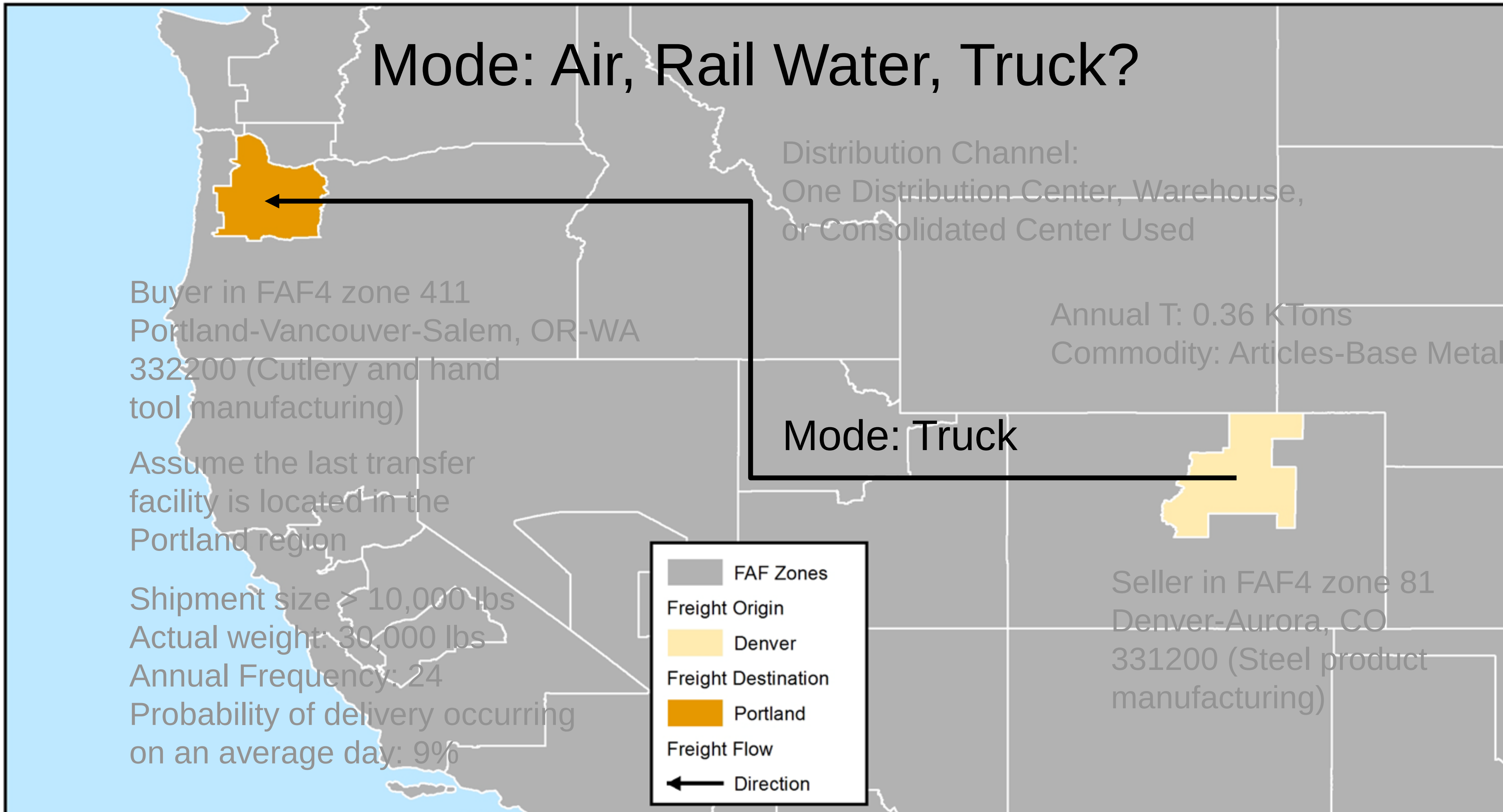
Annual T: 0.36 KTons
Commodity: Articles-Base Metal

Assume the last transfer facility is located in the Portland region

Seller in FAF4 zone 81
Denver-Aurora, CO
331200 (Steel product manufacturing)

Shipment size > 10,000 lbs
Actual weight: 30,000 lbs
Annual Frequency: 24
Probability of delivery occurring on an average day: 9%

Sample Model Sequence: Supply Chains



Freight Truck Touring Model

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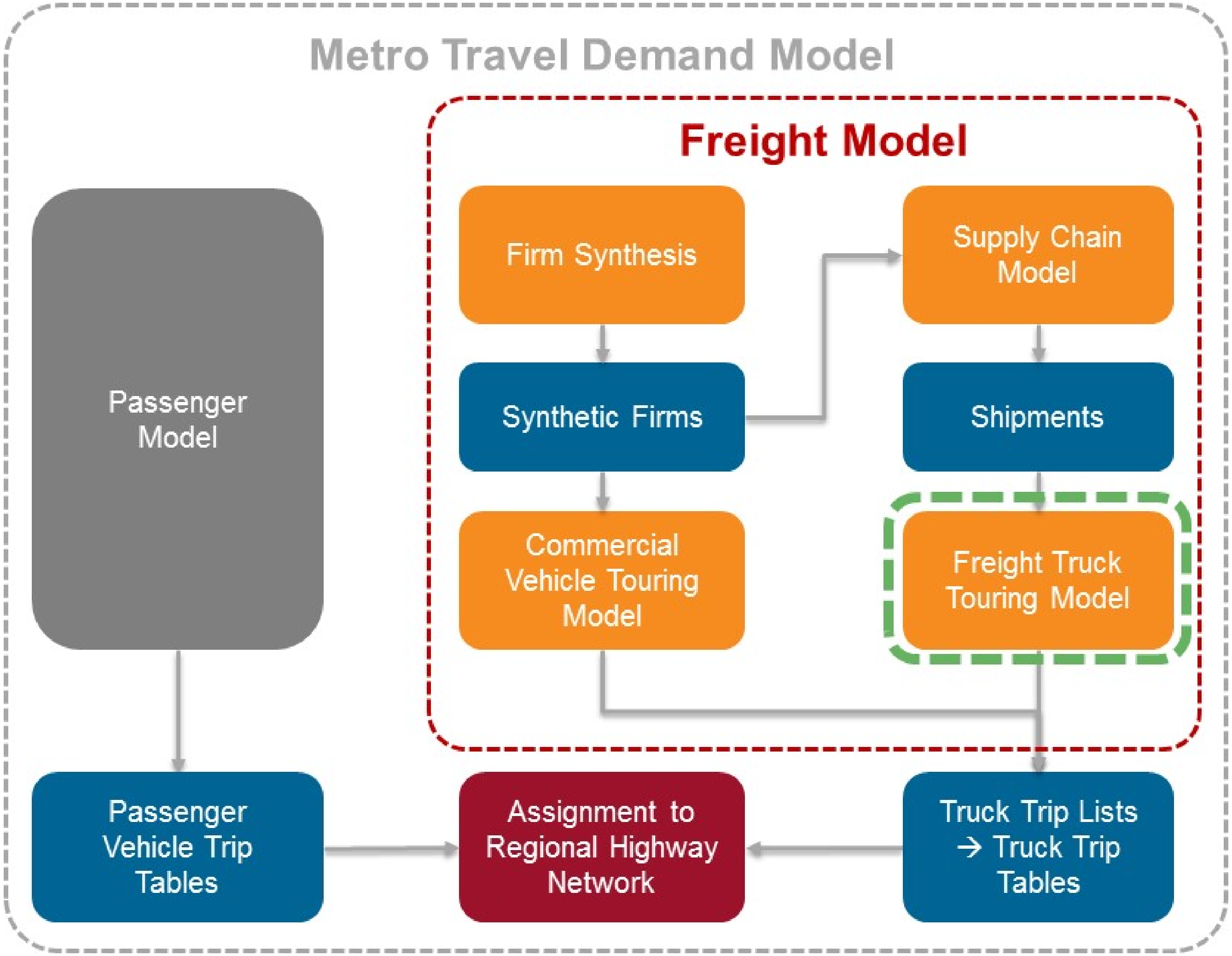


Supply Chain to Truck Touring Integration

For the truck touring model:

- A daily sample is taken for all shipments to, from, and within the metropolitan region
- The truck touring model simulates the truck portions of those shipments
  - Direct distribution channel shipments to or from outside the region are modeled as trips to or from external stations
  - Direct distribution channel shipments within the model region are modeled as trips from firm to firm
  - For trips with more complex distribution channels, the warehouse/distribution center location is simulated and truck tours built to represent pick up and delivery within the region

Freight Truck Touring Components

- Annual shipments generated by Supply Chain simulation are sampled
- Drayage and direct shipments identified
- Remaining shipments will be peddled (delivery/pick-up)
- Delivery/Pick-up times simulated
- Peddled shipments are clustered and routed into tours
- Departure/arrival times simulated
- Freight trucks may generate "intermediate" stops in between deliveries/pick-ups and return home

1. Truck Shipments (Supply Chain)

↓

2. Daily Sample

↓

3. Ports of Entry/Exit

↓

4. Vehicle Choice and Tour Pattern

↓

5. Stop Clustering

↓

6. Arrival Time at First Stop

↓

7. Routing Sequence

↓

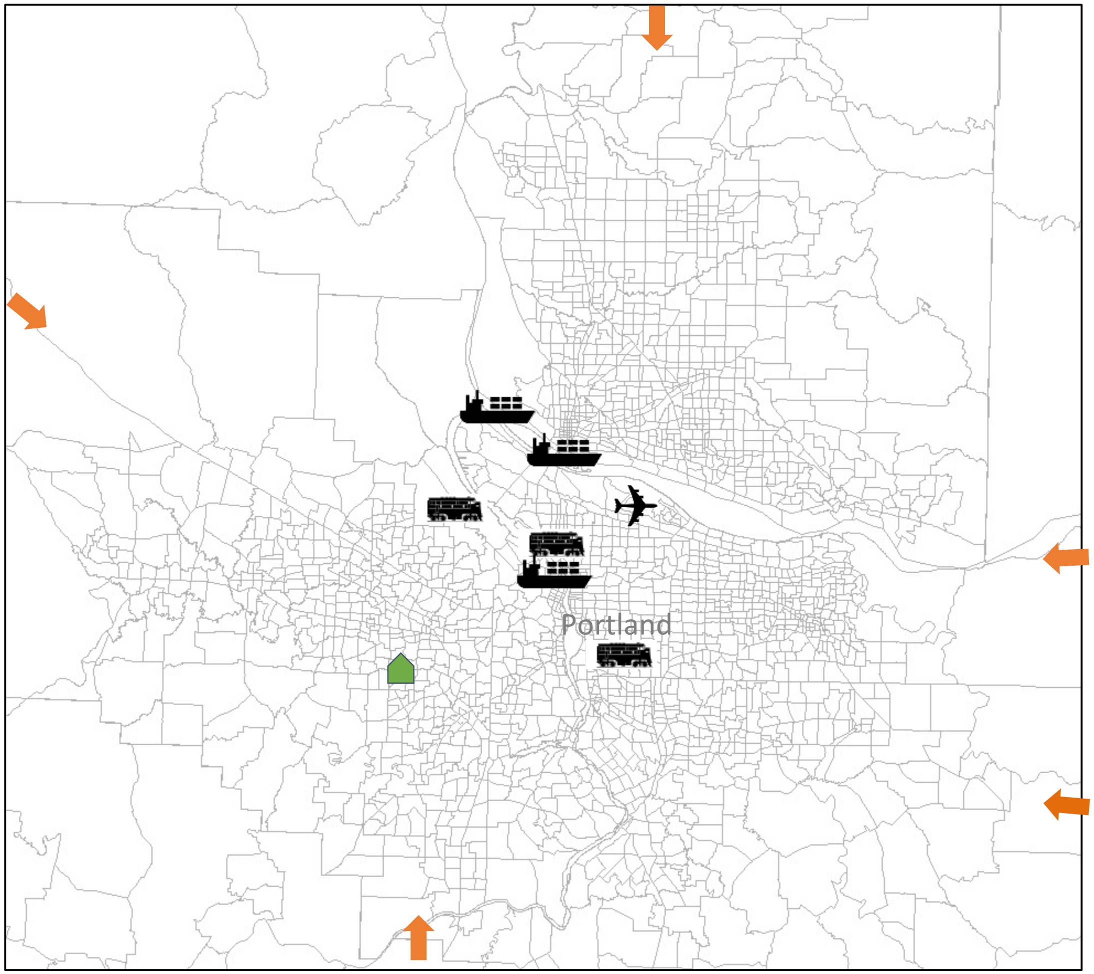
8. Intermediate Stop Choice

↓

9. Intermediate Stop Destination

Ports of Entry / Exit

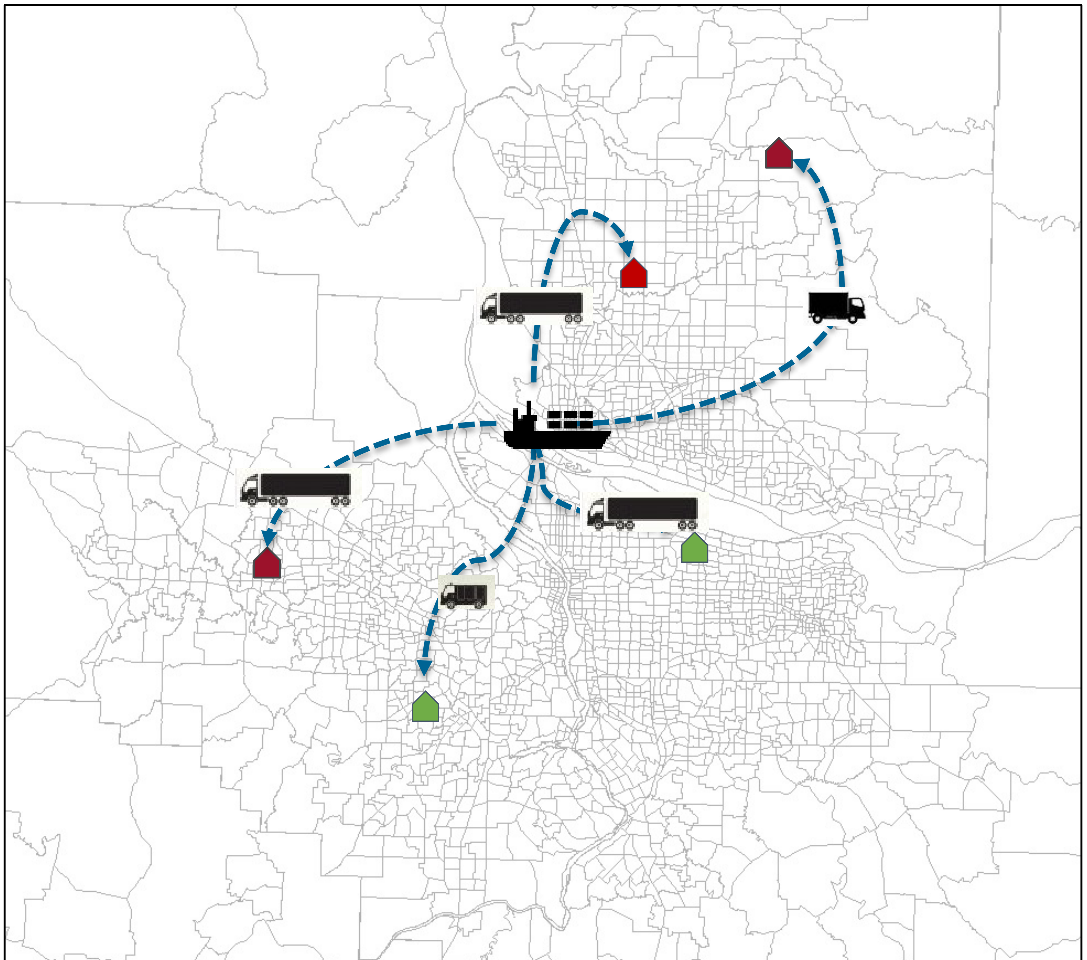
A portion of the model area



- After daily sample of shipments is taken, entry points into model region are simulated given shipment's freight mode:
  - Truck
  - Rail
  - Air
  - Water

- Intermodal Facilities:
  - Ports
  - Railyards
  - Airports
- External stations
  - Entry/exits for trucks
- Shipment destination

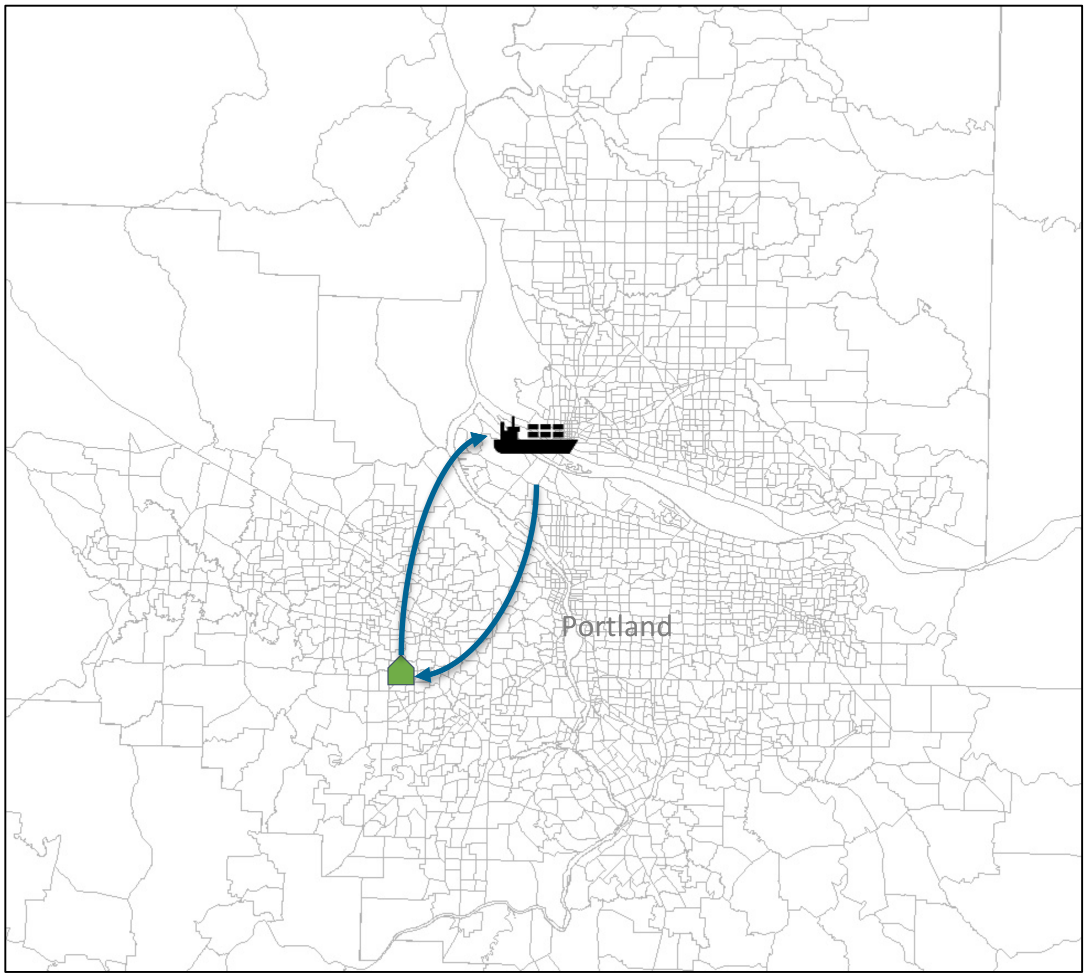
POE Vehicle Choice and Tour Pattern



- From port of entry, shipments may go
  - •Direct to destination
  - •To distribution center
- Logit model simultaneously predicts this tour pattern and vehicle choice
  - •Light
  - •Medium truck
  - •Heavy truck (semi)
- Vehicle choice constrained by shipment size and capacity
- Direct shipments routed into simple out-and-back tour

FTTM: Vehicle Choice and Tour Pattern (cont.)

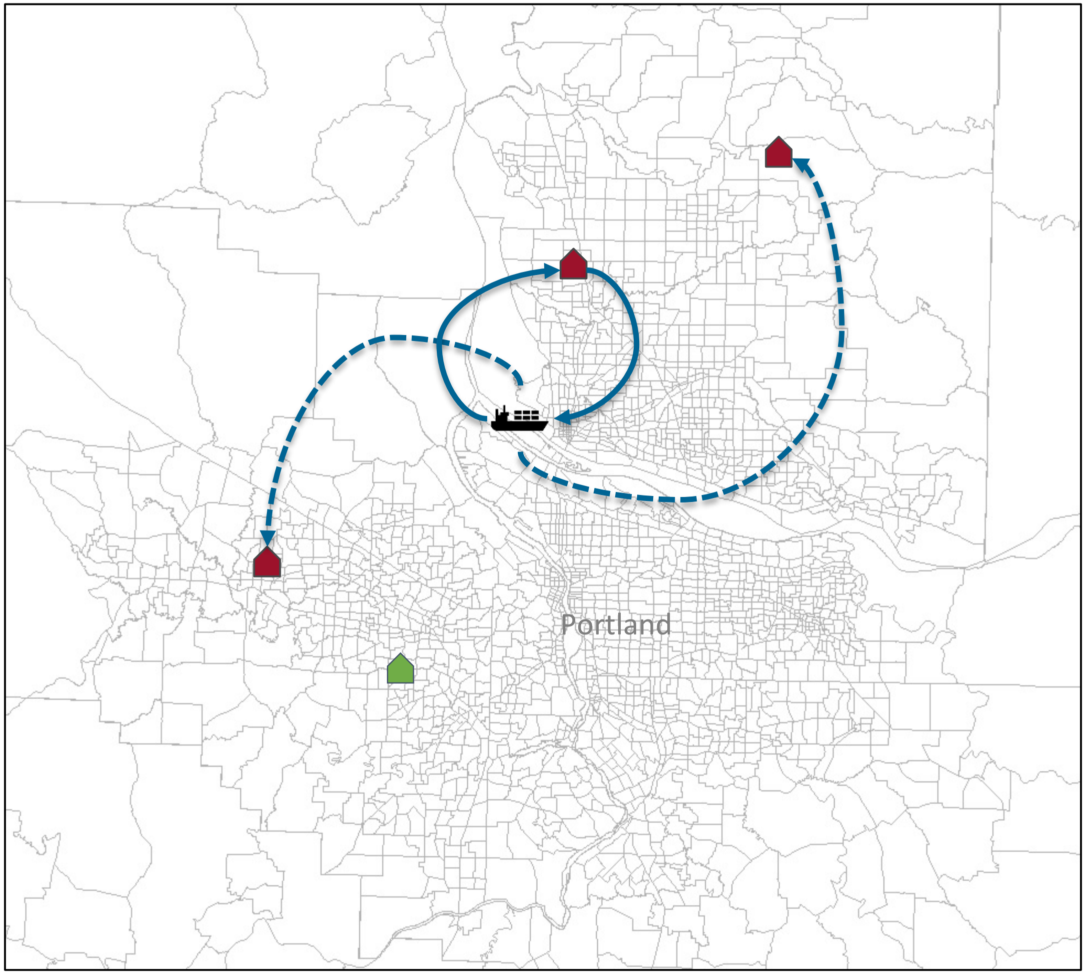
A portion of the model area



- Direct shipments routed into simple out-and-back tour
- Some shipment contracts may require multiple shipments per day
- Vehicles loaded to capacity and enough tours created to deliver all shipments
- Result: trip list of non-peddled shipments

FTTM: Vehicle Choice and Tour Pattern (cont.)

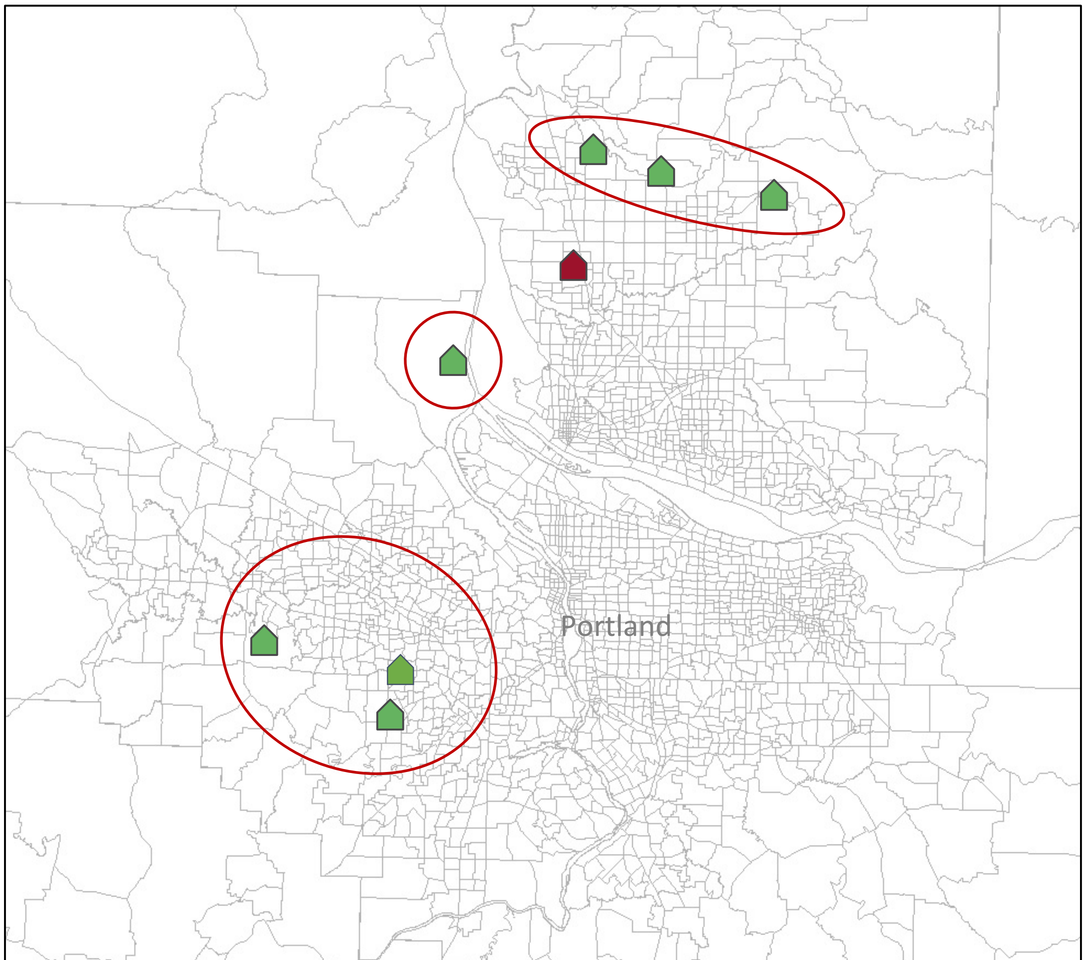
A portion of the model area



- Shipments transiting via distribution center to be placed on peddling tours
- Specific distribution center chosen, weighted by daily truck flows
- Return trip back to port of entry added

FTTM: Stop Clustering Model

A portion of the model area



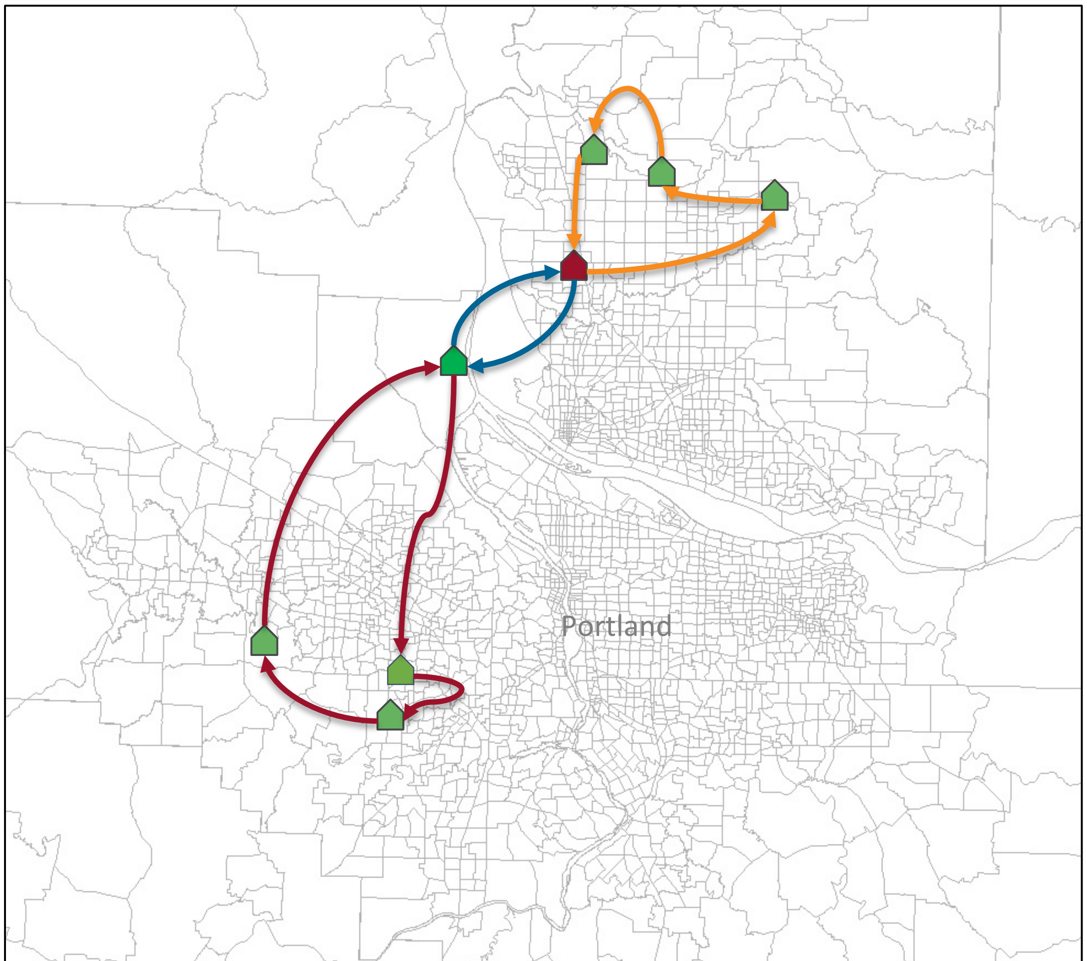
- Peddled shipments accumulate at each distribution center

For each distribution center and vehicle type…

- Hierarchical clustering groups spatially similar (travel time) destinations into tours
- Weighted branch trimming prevents overly long tours without creating too many short tours
  - Based on stop duration as travel not known (stops not yet sequenced)
  - Also avoids overburdening vehicles

FTTM: Stop Sequencing Model

A portion of the model area

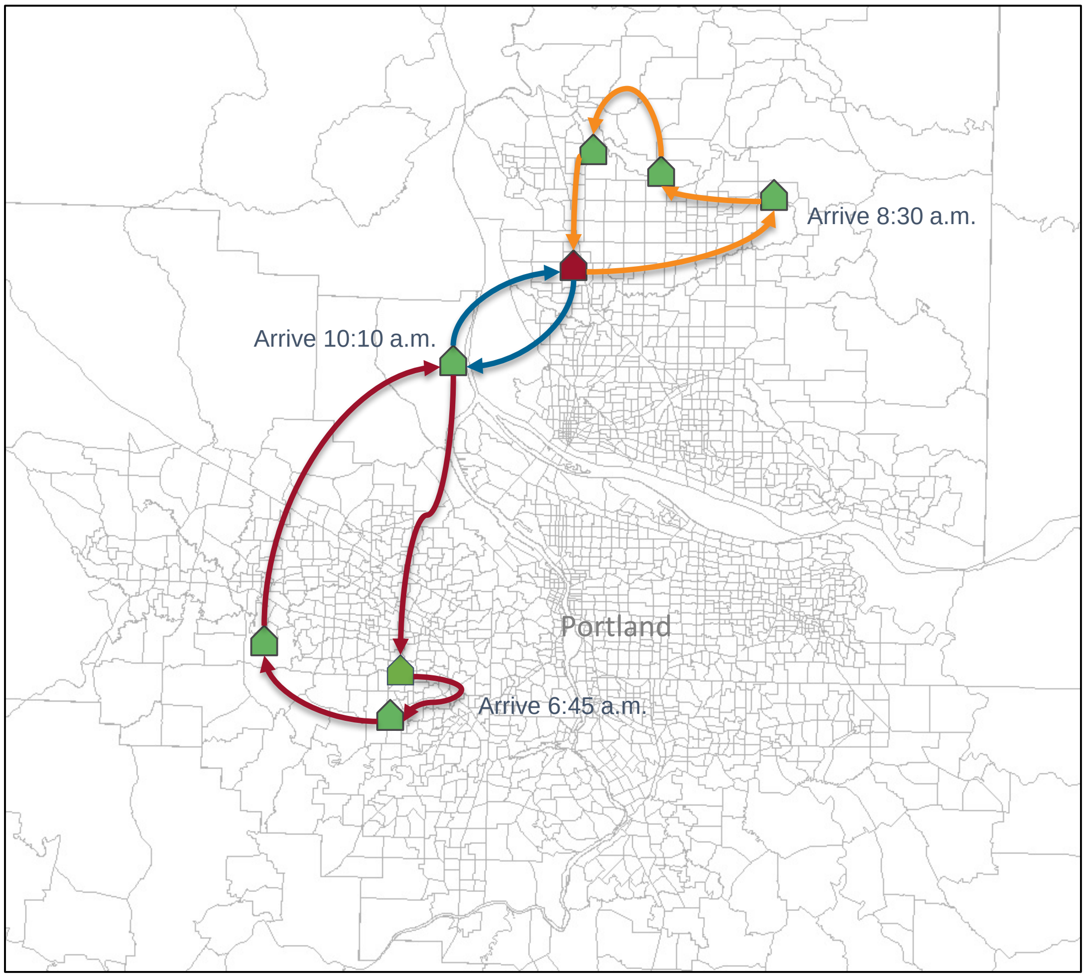


For each tour…

- Stops sequenced using Traveling Salesman algorithm on travel time combinations
- Provides reasonably short Hamiltonian circuits
- Avoids unrealistic tour patterns but not a true optimization
- Computationally feasible and generates realistic touring patterns

FTTM: First Stop Arrival Time Model

A portion of the model area

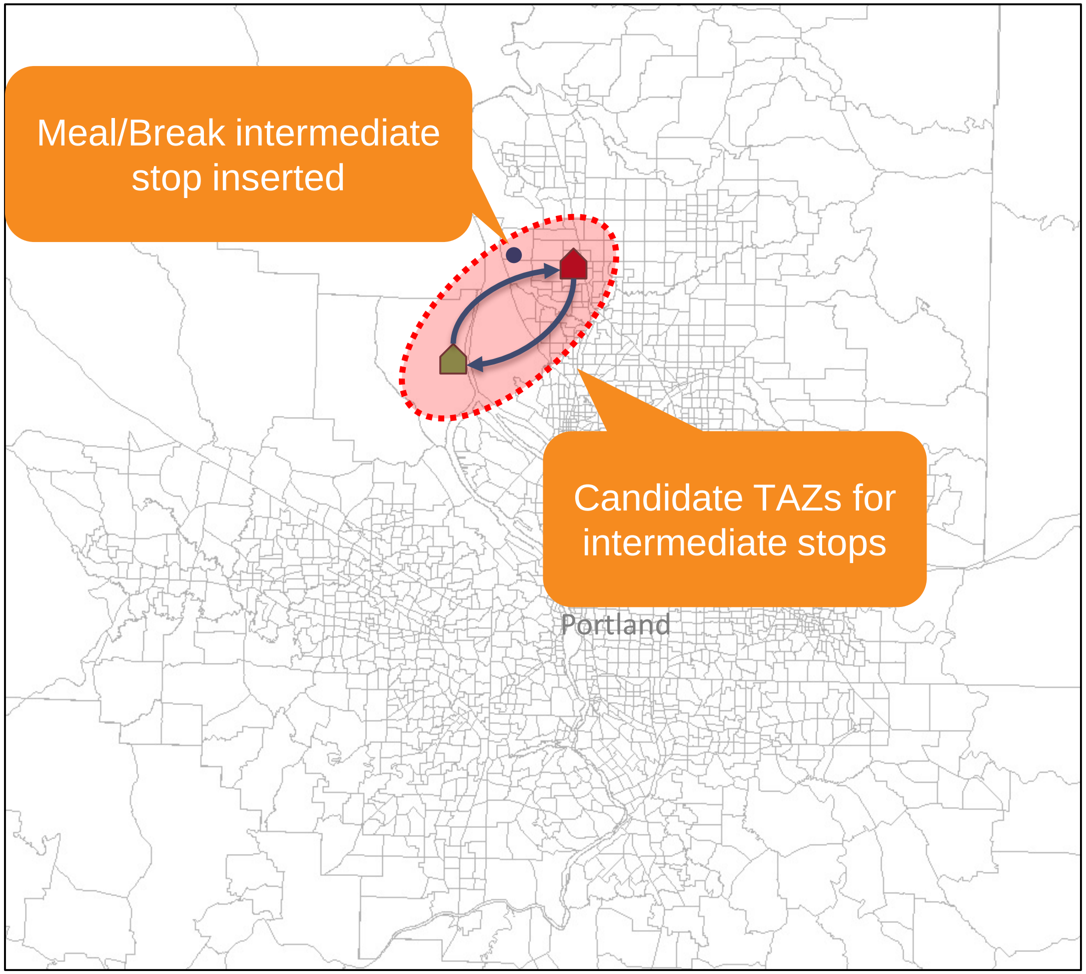


For each tour…

- MNL predicts arrival time at first scheduled stop as function of tour length
- Simulated arrival time windows of 30 to 60 minutes
- Monte Carlo simulation uniformly draws from selected arrive time window for precise arrival time

FTTM: Intermediate Stop Model

A portion of the model area



For each trip…

- Intermediate stop MNL model predicts whether an intermediate stop is inserted
  - Meal/break
  - Refueling/vehicle service
  - Other
- TAZs considered do not extend length of trip by some threshold (e.g., 3 miles)
- Stop duration model applied to any inserted stops
- Once all stops and order are known, trip is re-timed to determine arrival/departure times

FTTM: Intermediate Stop Model (cont.)

A portion of the model area

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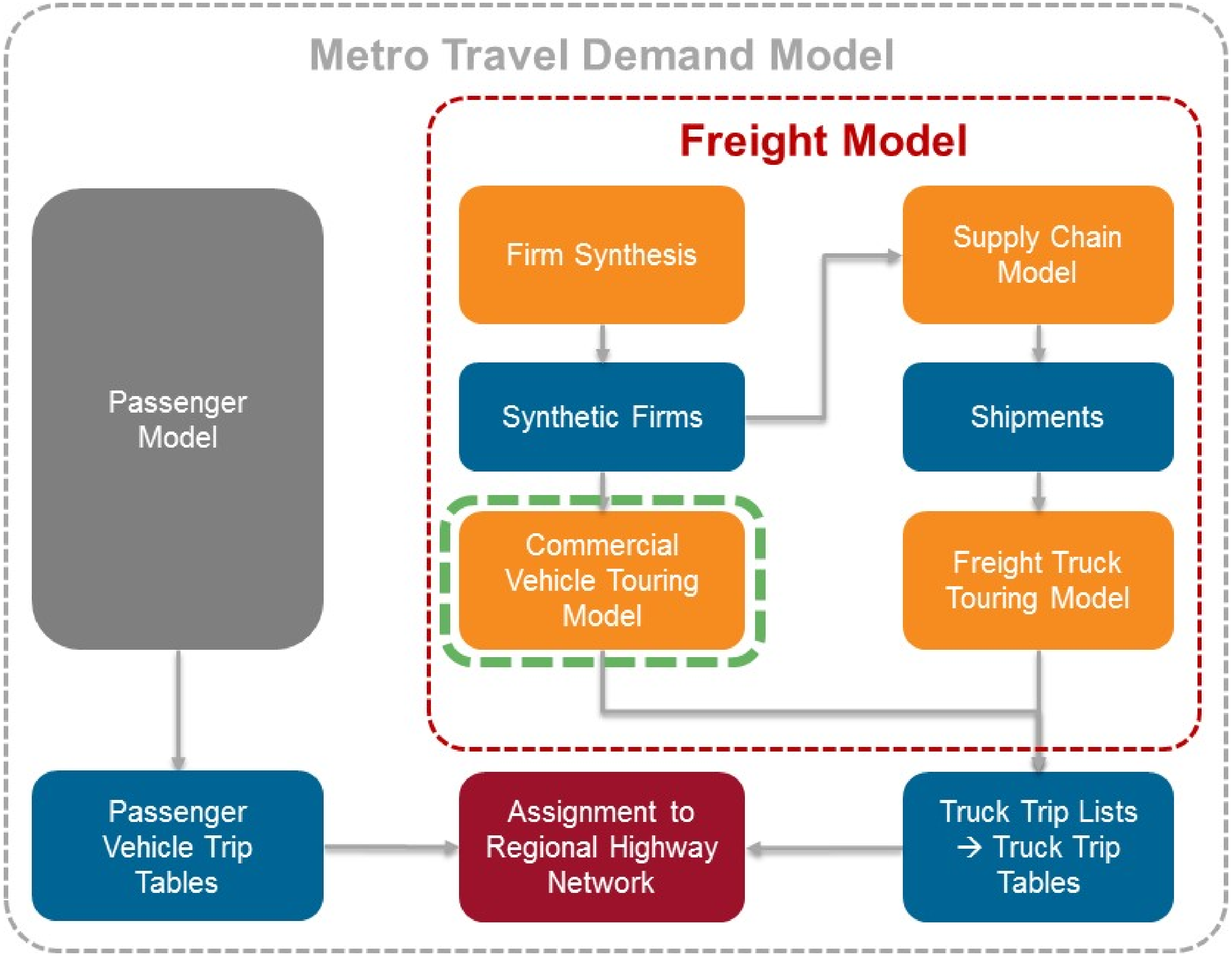
Commercial Vehicle Touring Model

Commercial Vehicle Touring Model



CVTM: Characteristics of Service Demand

Demand is not generated from regular commodity flows

Infrequent demand by individual customers, many of whom are private residences

Destinations with no firm or residence are common (public utilities, road construction, parks, schools)

Short time horizons for service calls/dispatching of commercial vehicles are common

- Some destinations may be considered “intermediate stops” (breaks/refueling)
- Pick up/drop off materials/equipment may be part of service provision

CVTM: Coverage

	Freight Truck Touring Model	Commercial Vehicle Touring Model
Vehicle Classes	Light, Medium, and Heavy	Light, Medium, and Heavy
Trip/stop purposes	Delivery of shipments to businesses	Service stops at all businesses and home, delivery of shipments to homes
Connections to external demand	Connected to external freight flows	Not influenced by external demand

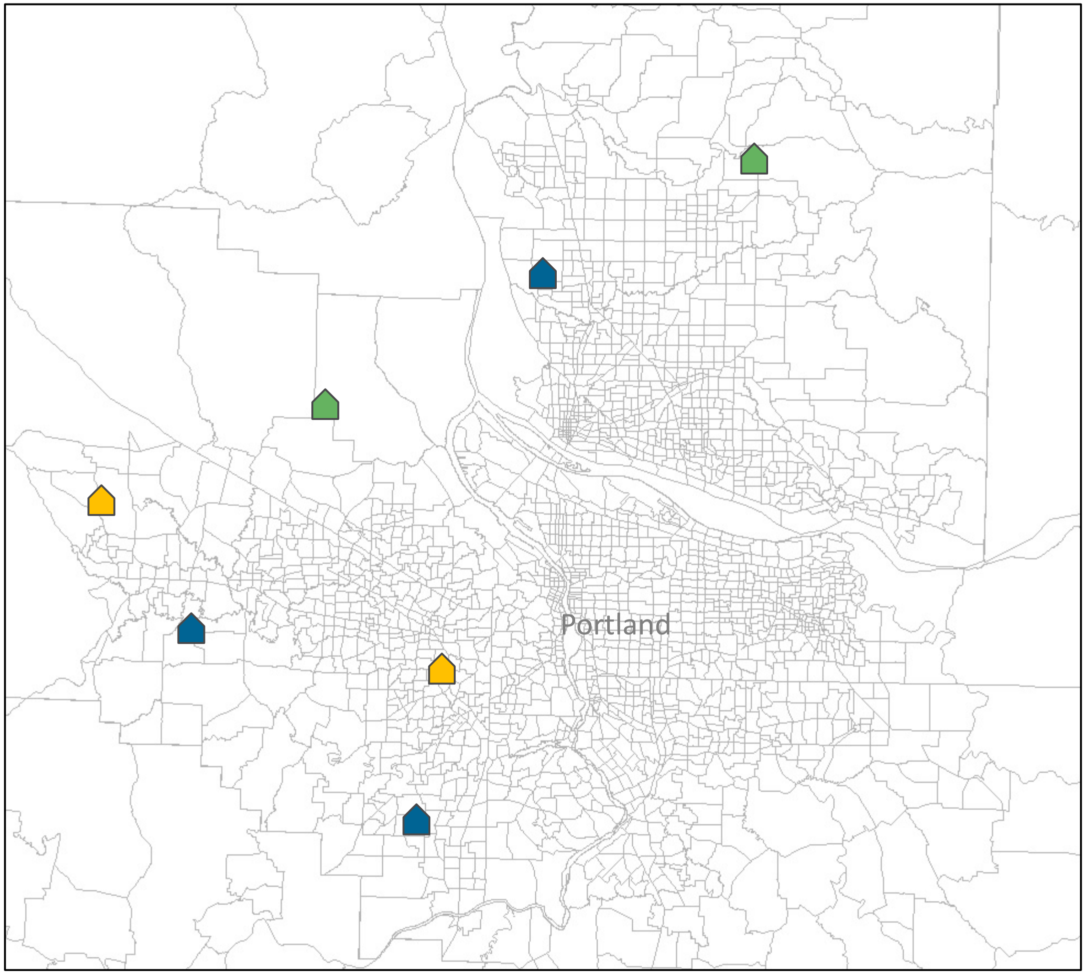
CVTM: Components

- Customers generate service stops by purpose, location and time of day (arrival time)
- Stop durations are predicted.
- Firms then choose whether to group assigned stops into a single tour or multiple-driver tours.
- Drivers sequence stops
- Firms may generate “intermediate” stops in between customer stops and return home.

1. Establishment Type
↓
2. Stop Generation
↓
3. Expected Stop Duration
↓
4. Vehicle Assignment
↓
5. Stop Clustering
↓
6. Arrival Time at First Stop
↓
7. Routing Sequence
↓
8. Intermediate Stop Choice
↓
9. Intermediate Stop Destination

CVTM: Establishment Type Model

A portion of the model area



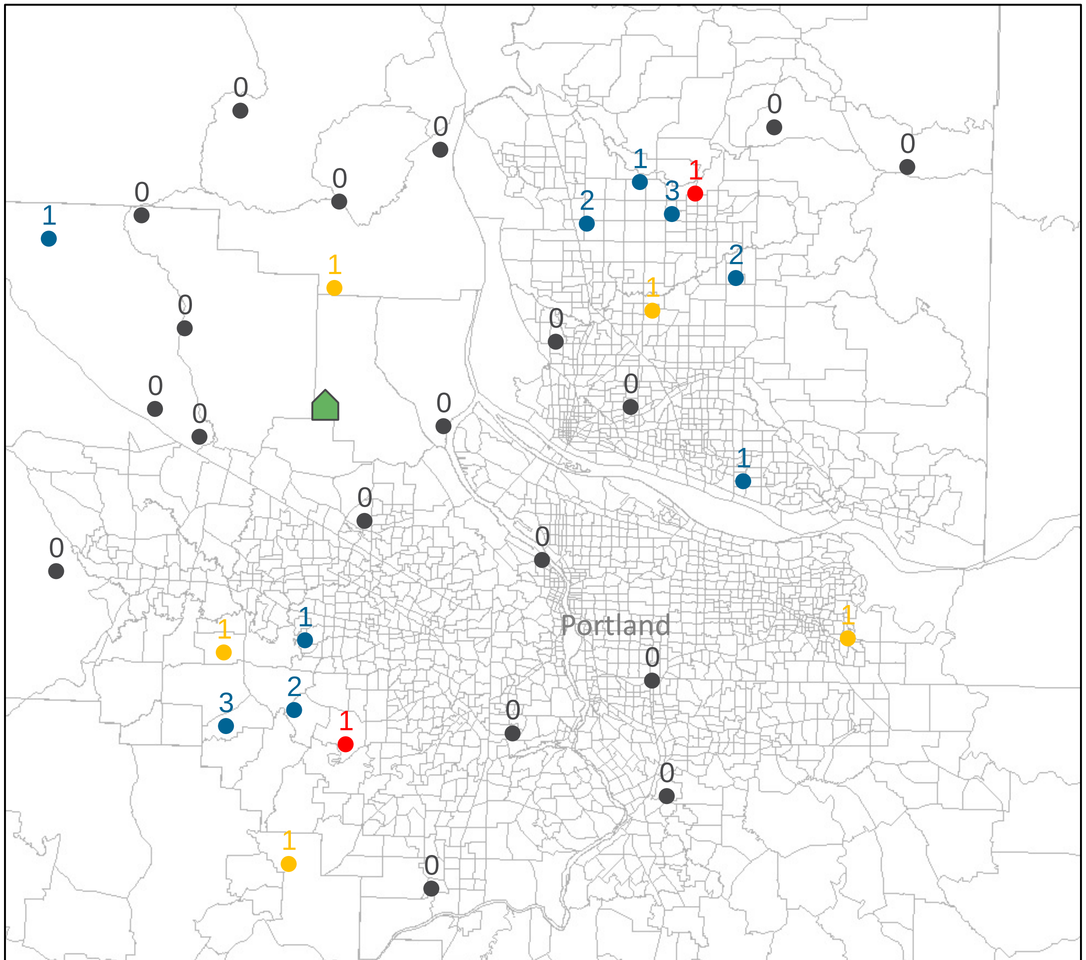
Note: not all firms depicted

For each synthesized firm…

- Predicts type of establishment:
  - Goods delivery
  - Services
  - Both
- Monte Carlo simulation used to draw from observed distributions of establishment types by industry

CVTM: Stop Generation Model

A portion of the model area



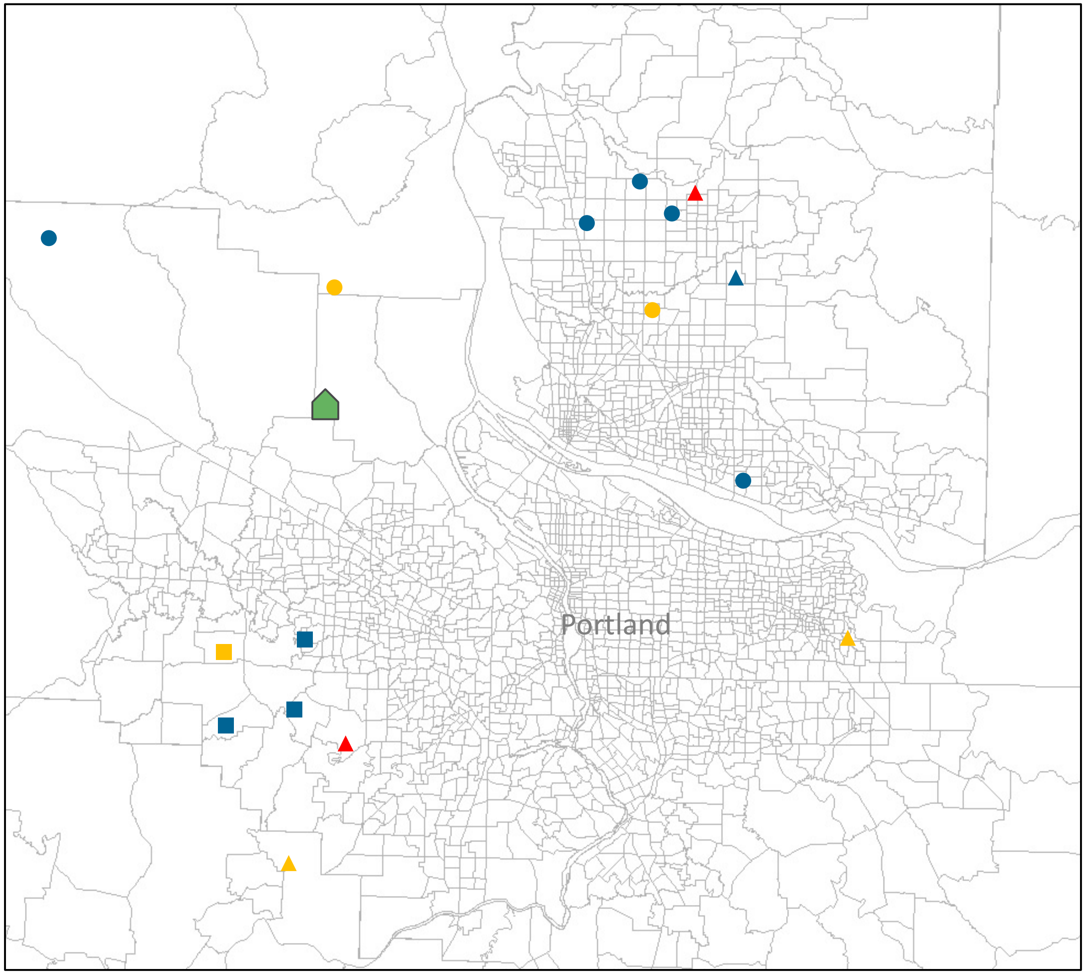
Note: not all system TAZs depicted

For each synthesized firm…

- TAZs sampled as candidates for stops
- Hurdle model predicts number of goods and service stops in each TAZ as applicable
- All firms may generate meeting stops as well
- Number of stops a function of firm size, industry, stop purpose, and TAZ socio-economic characteristics

CVTM: Vehicle Assignment Model

A portion of the model area

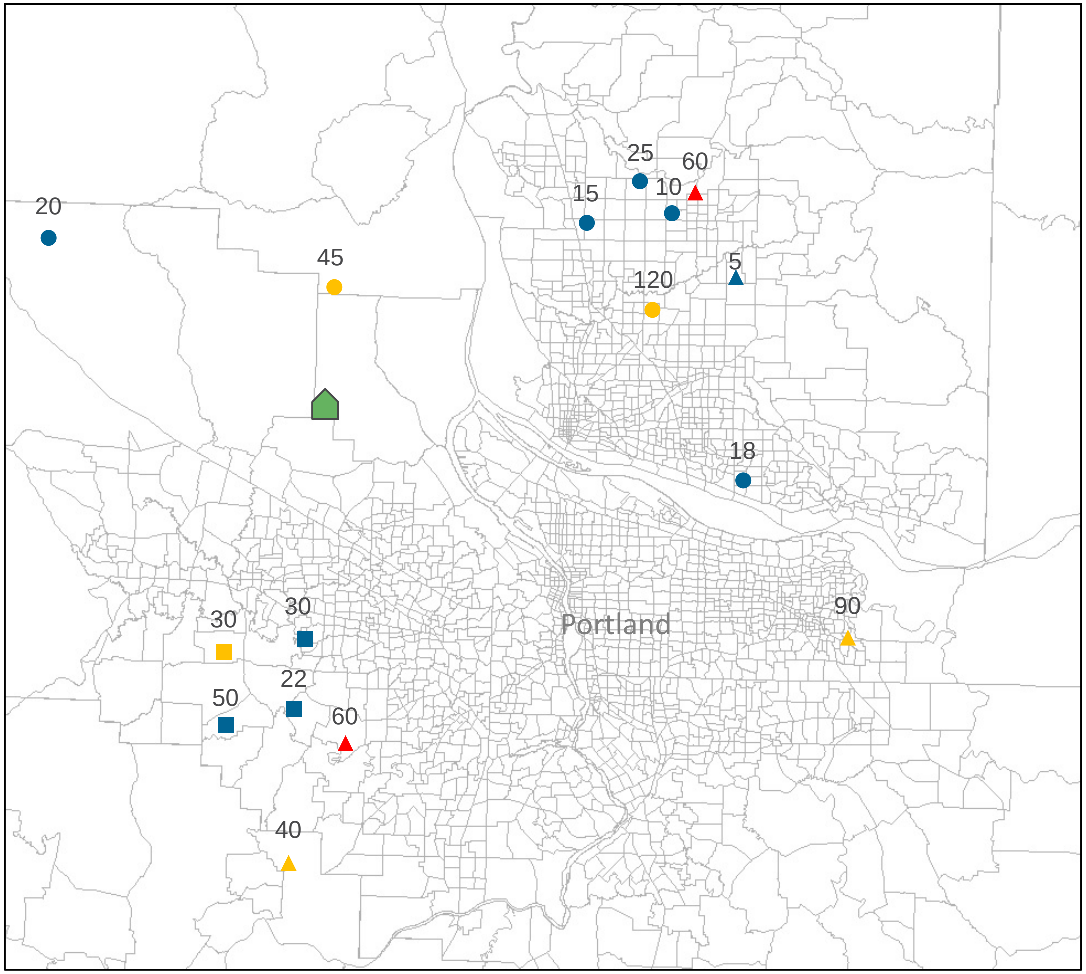


For each stop…

- MNL model predicts commercial vehicle type for each stop:
  - Light: car, van, pickup
  - Medium: single-unit truck
  - Heavy: multi-unit truck
- Vehicle type a function of:
  - Firm industry
  - Distance
  - Stop purpose

CVTM: Stop Duration Model

A portion of the model area

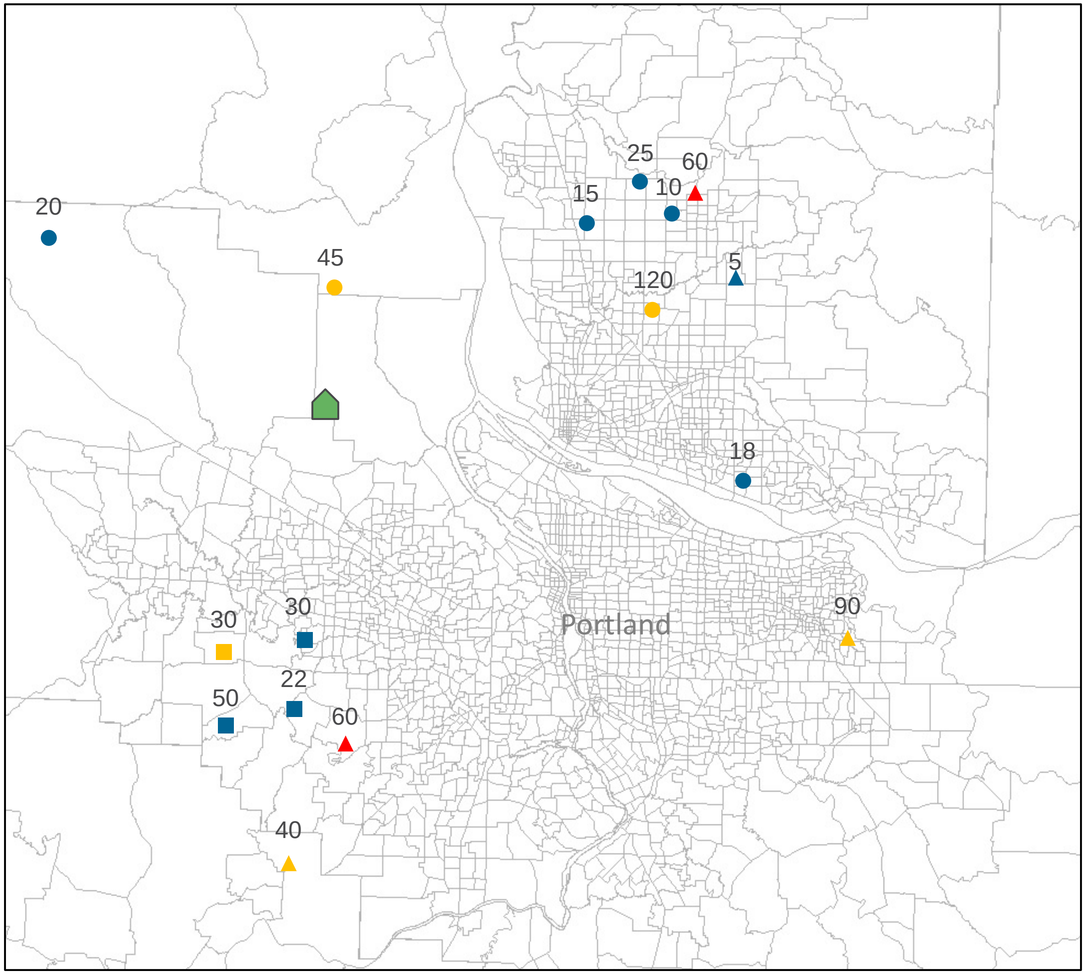


For each stop…

- Stop duration (minutes) drawn via Monte Carlo simulation from empirical distributions by:
  - Industry
  - Stop purpose

CVTM: Stop Clustering Model

A portion of the model area



For each vehicle type…

- Hierarchical clustering groups spatially similar (travel time) stops into tours
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CVTM: Stop Clustering Model

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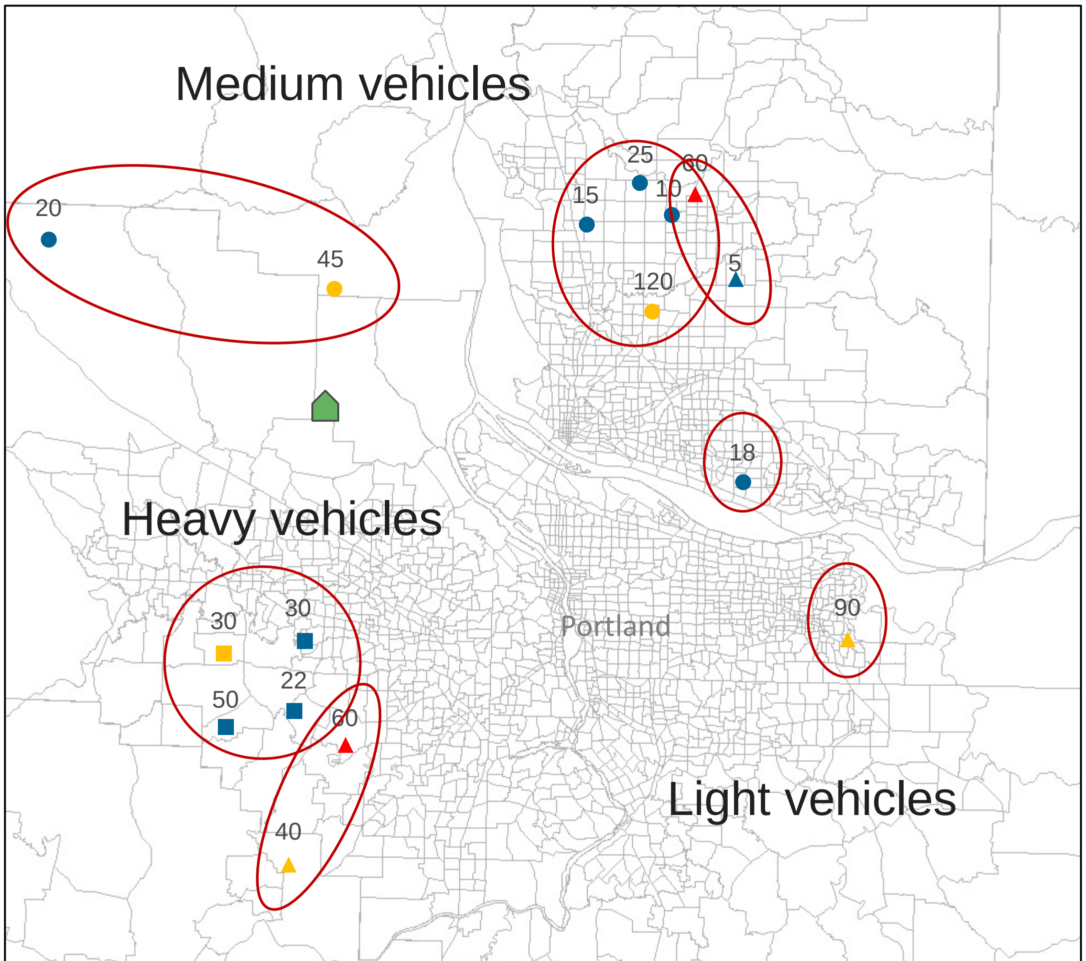

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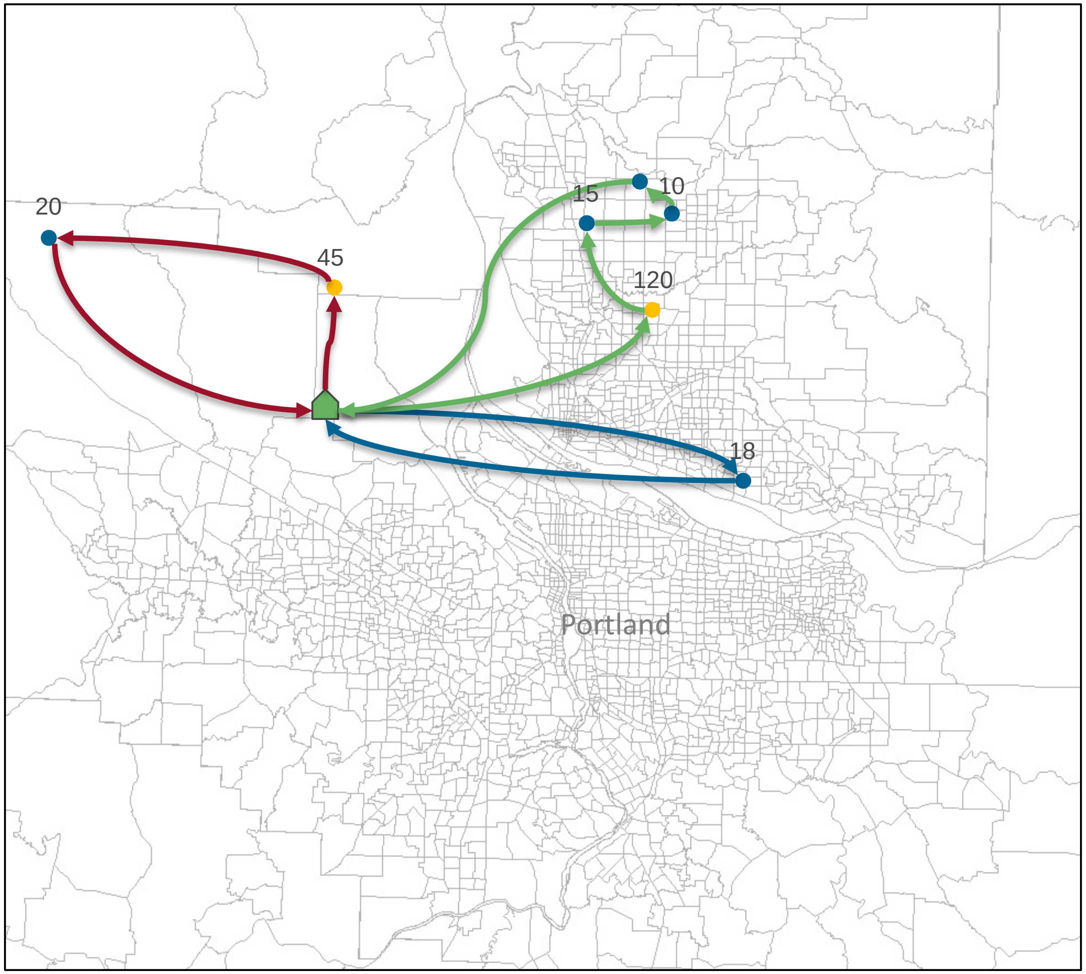
CVTM: Stop Sequencing Model

A portion of the model area



For each tour…

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CVTM: First Stop Arrival Model

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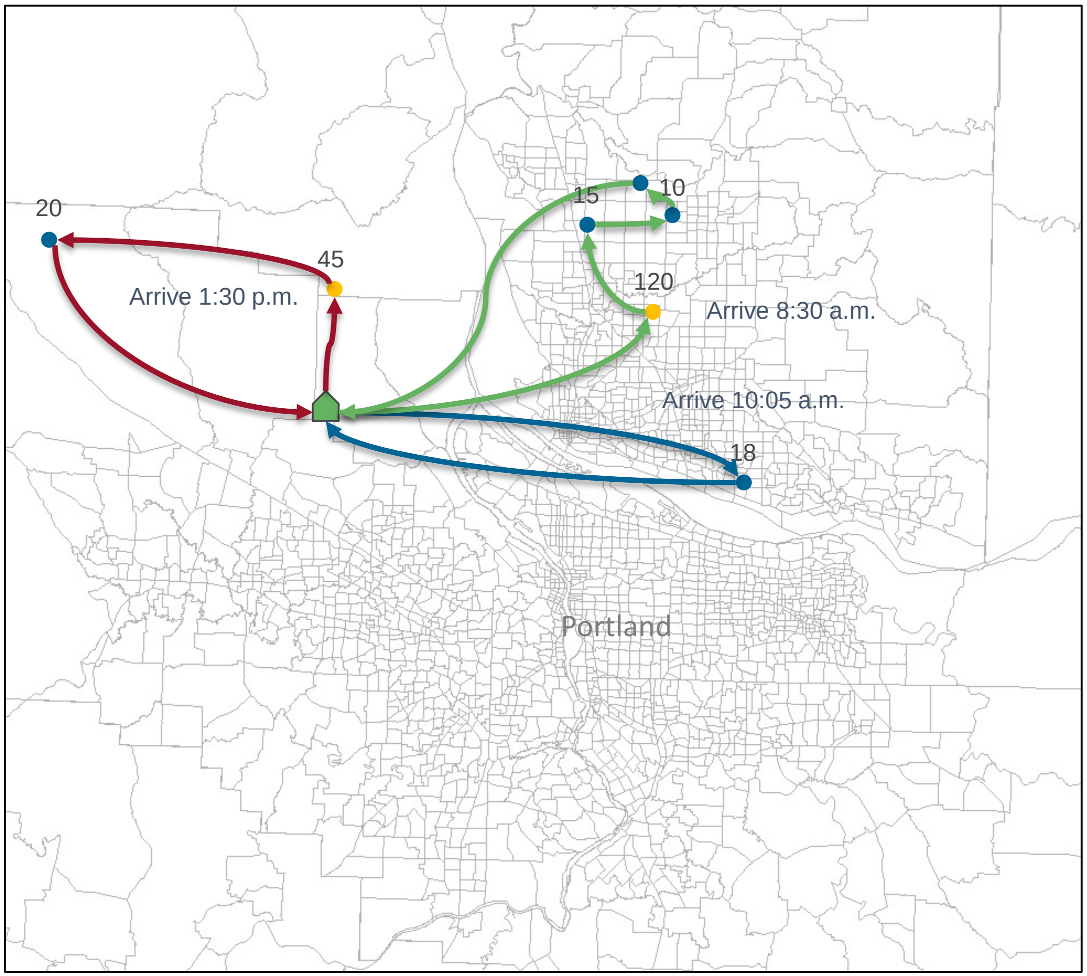

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CVTM: Intermediate Stop Model

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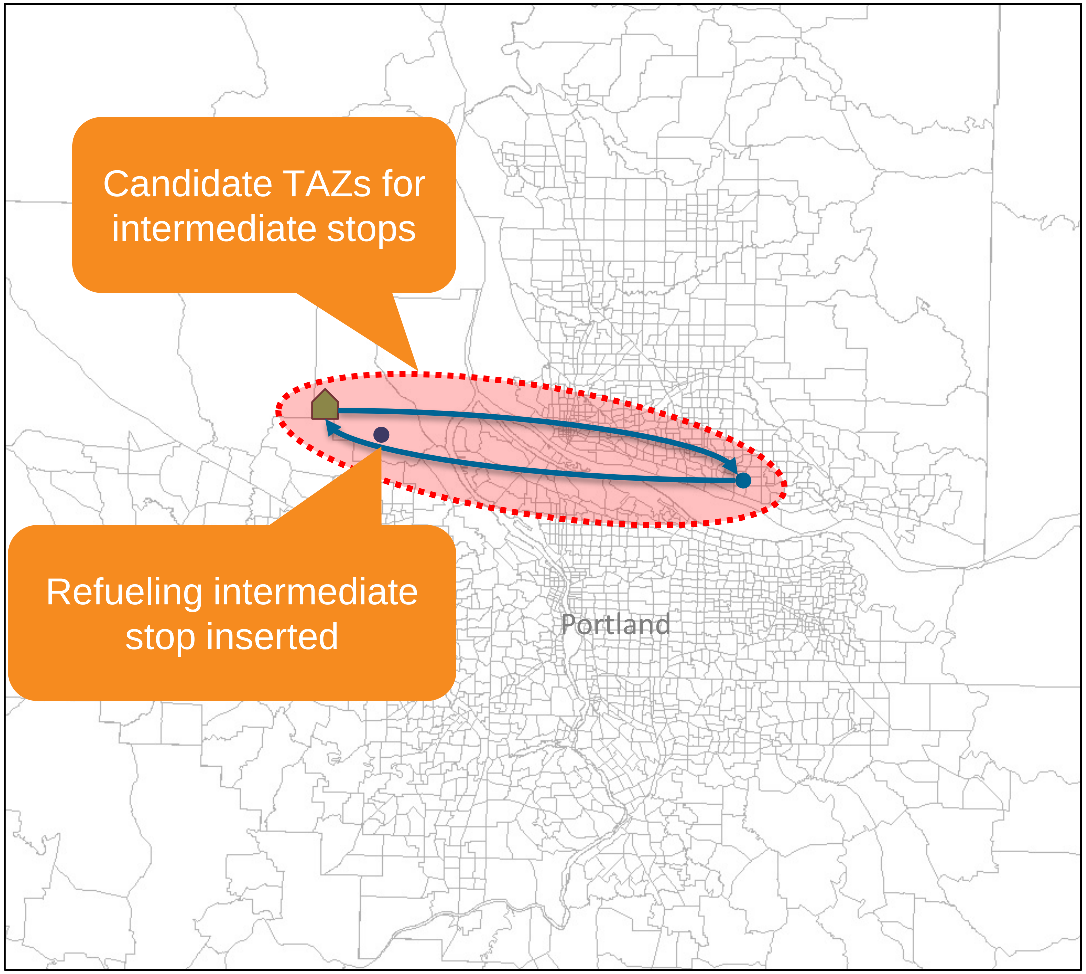

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CVTM: Intermediate Stop Model (cont.)

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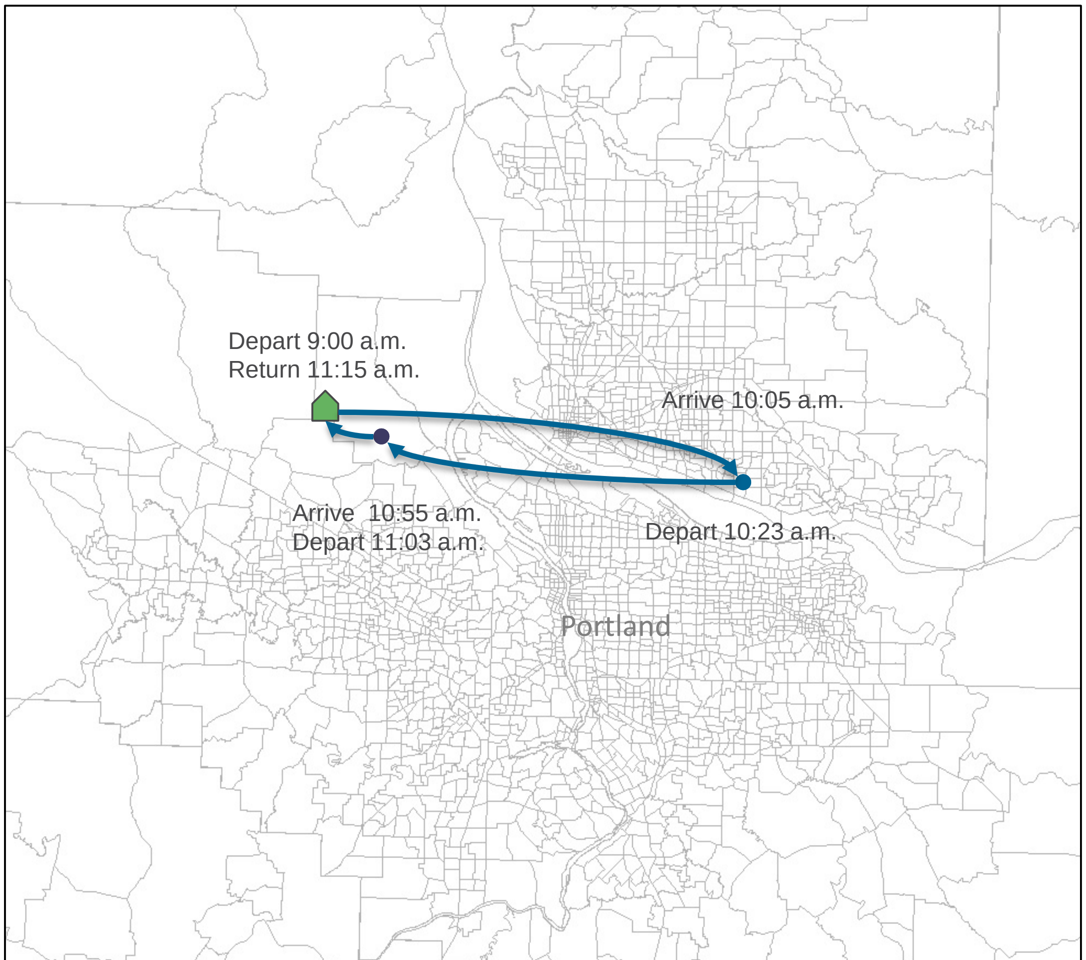

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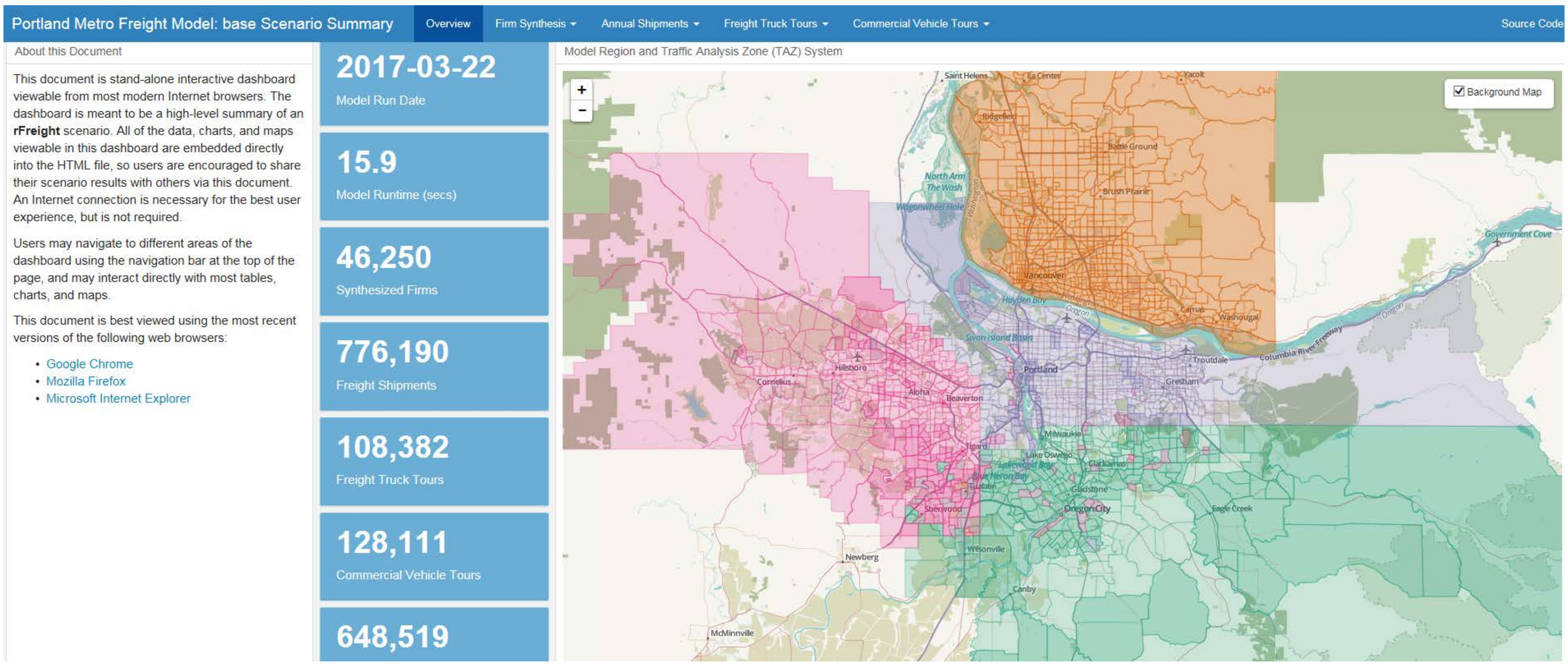
Dashboard

Dashboard


Portland Metro Freight Model: base Scenario Summary
Overview
Firm Synthesis
Annual Shipments
Freight Truck Tours
Commercial Vehicle Tours
Source Code
About this Document
This document is stand-alone interactive dashboard viewable from most modern Internet browsers. The dashboard is meant to be a high-level summary of an **rFreight** scenario. All of the data, charts, and maps viewable in this dashboard are embedded directly into the HTML file, so users are encouraged to share their scenario results with others via this document. An Internet connection is necessary for the best user experience, but is not required.
Users may navigate to different areas of the dashboard using the navigation bar at the top of the page, and may interact directly with most tables, charts, and maps.
This document is best viewed using the most recent versions of the following web browsers:
Google Chrome
Mozilla Firefox
Microsoft Internet Explorer
2017-03-22
Model Run Date
15.9
Model Runtime (secs)
46,250
Synthesized Firms
776,190
Freight Shipments
108,382
Freight Truck Tours
128,111
Commercial Vehicle Tours
648,519
Model Region and Traffic Analysis Zone (TAZ) System
Background Map
Portland
Vancouver
Hillsboro
Beaverton
Gresham
Troutdale
Oregon City
Newberg
McMinnville
Canby
Wilsonville
Sherwood
Tigard
Milwaukie
Camas
Washougal
Battle Ground
Brush Prairie
Ridgefield
Saint Helens
Cornelius
Aloha
Lake Oswego
Clackamas
Gladstone
Eagle Creek
Columbia River Freeway

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